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I.—The Iron-fields of Lorraine.

By R. H. Rastall, M.A., F.G.S.

RECENT events have again called attention to the enormous strategic and economic importance of the iron-fields of Lorraine; on these much of the commercial prosperity of Germany has been built up in the past, and on their possession her future as an industrial nation largely depends. For many years the output of iron-ore from the part of Lorraine under German control has been immense: in 1912, German Lorraine produced approximately 20,000,000 tons, while the output of Luxemburg, which, for all practical purposes, is German, was about 6,500,000 tons. In the same year the French portion of the Lorraine iron-field yielded 17,300,000 tons, making a grand total for this area of 43,800,000 tons of ore. During the War the whole of the French productive region has been occupied by the enemy, and there is no means of ascertaining what has actually happened there, but certain inferences can be drawn from published facts and on a basis of probability.

First, however, it is necessary to consider briefly the geographical distribution and geological structure of these regions. The Briey plateau forms a somewhat elevated region extending from the southern border of the Ardennes to a little south of Metz: it is dissected by the valleys of several rivers, including the Moselle, Orne, Fentsch, Algringen, and Meurthe. Geologically the plateau is composed of Jurassic rocks, chiefly Lias and Dogger, and it is near the boundary of these two series that the beds of iron-ore occur. By German geologists they are referred to the Dogger, by French authorities mostly to the Lias. According to Van Werveke they belong to the zone of *Ammonites Murchisonæ*.

The Briey field is nearly 40 miles long, with a width of about 15 miles, within which the ore is believed to be payable; south of it comes a barren region extending for some 15 miles and then the Nancy field, which is about 13 miles long. The Lorraine plateau as a whole is divided by rivers and other natural boundaries into several subsidiary regions, while the basins of Longwy and Crusnes are of considerable importance. In the French portion of the Briey field the chief subdivisions recognized are those of Orne, Landres, and Tucquegnieux.

The general geological structure is very simple, as the whole series dips gently to the west. The iron-bearing beds outcrop on the eastern side of the plateau a few miles east of the frontier and in the south of Luxemburg, hence they naturally become deeper and

deeper towards the west in French territory. On the east and south the thickness is from 50 to 70 feet, but this increases to about 200 feet westwards and in Luxemburg, with a corresponding falling off in quality. The ferruginous series consists of an alternation of beds of oolitic iron-ores of various colours with limestones and occasional marls. The iron-ores, which are locally known as Minette, have been formed by metasomatic replacement of calcareous oolitic grains, probably consisting originally of aragonite, while the cement has chiefly remained calcareous. As before stated, the percentage of iron varies regularly from north to south, and this has a most important economic bearing. In Luxemburg the average iron-content is 30 per cent or less, while in the south of the Briey plateau it rises to as much as 40 per cent, with 9 to 14 per cent of lime and 4 to 7 per cent of silica. In the Longwy and Crusnes fields the ores contain less lime, while the silica rises to 20 per cent in some cases; the proportion of phosphorus remains very constant throughout, averaging about 1·8 per cent.

Hence the ores must be regarded as distinctly phosphatic, and it was the introduction of the Thomas-Gilchrist process in 1882 that led to the vast industrial development of this area.

Several careful computations of reserves have been made, and the following figures are estimates of ore still available in the different districts and workable under present economic conditions :—

	Tons.
Briey	2,000,000,000
Longwy	275,000,000
Crusnes	500,000,000
German Lorraine and Luxemburg	2,000,000,000
Total	4,775,000,000

Of this total considerably more than half was in French territory, including practically the whole of the higher-grade portion. The potentialities of the western portion of the Briey plateau were not known to the German authorities when peace was concluded in 1870, and an endeavour to rectify the mistake then made must certainly be regarded as one of the causes of the present War. The whole of the Briey field as well as those of Longwy and Crusnes are occupied by the Germans, and it is of interest to consider what is now going on there. Lately published statistics relating to Luxemburg throw some indirect light on the matter. In 1912 the output of Luxemburg was 6,511,000 tons, and in 1916 6,752,000 tons. In 1917 the output fell suddenly to 4,502,000 tons, and in August, 1918, some 450,000 tons still remained unsold in that country, owing to excess of supply over demand. The consumption of iron-ore in Germany at the present time is undoubtedly very great, and the natural inference is that Germany is now exploiting as largely as possible the richer ores of the Briey plateau and neglecting the poorer ones of German Lorraine and Luxemburg. It is also stated that there is an active demand for siliceous ores, as opposed to the more calcareous varieties, and it is a natural inference that ore of this kind is being obtained from the Longwy

and Crusnes fields. Hence it is clear that German munitions of war are being very largely manufactured from French ore, thus diminishing the potential mineral wealth of that country, in addition to the actual damage inflicted by the said munitions during the War. These are facts which will have to be taken into consideration at the Peace Conference.

II.—Additional Notes on the Petrography of South Georgia.

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THE rocks which form the subject of this paper were collected by the captain of a whaling vessel belonging to the fleet of Messrs. Salvesen & Co., of Leith, stationed at Leith Harbour, South Georgia. The collection reached me, for description, through the kind offices of Mr. D. Ferguson, Mem. Inst. M.E., who recently visited the island, and who has described its geological features.[1] Two previous collections of rocks from South Georgia have been described by me, one collected by Mr. Ferguson during his visit,[2] the other collected in the same way as the present set.[3]

The collection consists of twenty-six specimens, nineteen of which are from Larsen Harbour, at the extreme south-eastern end of the island, in the midst of the "altvulcanischer" area found by Heim.[4] Three specimens are from Gold Harbour, on that part of the coast that trends nearly due north and south near the south-eastern end; and four specimens are from King Haakon Harbour, about the middle of the long, icebound, southern coast. Most of the material is igneous, or derived from igneous rocks by alteration; the few remaining specimens belong to the sedimentary series of which the greater part of South Georgia is built. The rocks may be classified as follows:—

1. Igneous Rocks and their Derivatives.
   - (1) Spilite.
   - (2) Soda-felsite (Quartz-felsite of previous paper).[5]
   - (3) Greenstone (Albite-dolerite?).
   - (4) Epidosite and other Vein Rocks.
2. Sedimentary Rocks.

1. Igneous Rocks.

(1) *Spilite.*—Several specimens belong to this type, all derived from Larsen Harbour. They are compact, grey-green, non-porphyritic rocks, carrying veins of quartz, chlorite, and epidote. In some specimens small amygdales of dark-green chlorite or yellowish-green epidote occur.

[1] "Geological Observations in South Georgia": Trans. Roy. Soc. Edin., vol. l, pt. iv, pp. 797–814, pls. lxxxi–xci, 1915.

[2] "Petrography of South Georgia": ibid., pp. 823–36, pl. xciv.

[3] "Further Notes on the Petrography of South Georgia": Geol. Mag., dec. VI, Vol. III, 1916, pp. 435–41.

[4] "Geol. Beob. ü. S. Georgien": Zeit. Ges. Erdk., 1912, pp. 451–6.

[5] Op. cit., p. 438.

In section, the most typical rock (C 10)[1] shows a thin network of slender striated felspars, with nearly straight extinction, interspersed with a few microphenocrysts which have a well-marked multiple twinning, and the extinction and refractive index of almost pure albite. The felspars of the groundmass are appreciably less sodic, and belong to albite-oligoclase. The interstices of the felspar network are filled with chalcedonic silica, chlorite (mostly in amygdales), epidote, a little quartz, very minute felspar microlites, and a dark-green indeterminate material. The chlorite amygdales are often lined with a thin layer of cryptocrystalline silica, and are further banded with concentric layers of slightly different varieties of chlorite, or chlorite mingled with grains and rods of epidote. There is not a trace of the original ferro-magnesian or iron-ore minerals. They have all been replaced by chlorite and epidote, with, no doubt, cryptocrystalline silica as a bye-product of the reaction. Thin veins of quartz, chlorite, and epidote occur in the rock. This is a fairly typical spilite.

Another specimen (C 11) shows the felspars still more thinly dispersed in a dense groundmass, consisting mainly of a greyish-green indeterminate material, with chlorite and a few felspar microlites, still showing traces of its original texture. There are numerous amygdales of uniform bright-green chlorite. The microphenocrysts of albite tend to segregate into small groups; and mingled with them are a few crystals of untwinned felspar, mottled in polarized light, which appear to be soda-orthoclase. In one part of the slide rounded areas of granular epidote become common.

A somewhat different type of spilite is represented by other specimens. In the mass they are dark-grey, compact rocks, with numerous spherical cavities filled with radiating needles of green epidote. In thin section they show numerous small laths of albite-oligoclase, with a few stouter microphenocrysts, in a dense groundmass consisting of minute felspar microlites, abundant grains of ragged skeletal iron-ores, and a pale yellowish-green fibrous chlorite which no doubt represents original pyroxene. Large euhedral crystals of magnetite are scattered sparingly over the section. Large rounded patches or amygdales of epidote and chlorite also occur, the epidote forming masses of radiating crystals, with rosettes of chlorite filling the remaining interspaces. Sometimes, however, chlorite fills the amygdale to the almost complete exclusion of epidote, and shows a remarkable violet polarization tint. Epidote and chlorite occur only sparingly in the groundmass of these rocks. They are to be regarded as falling midway between the typical spilites and the more mafic varieties described below.

Two of the rocks (C 18, C 19) are richer in mafic constituents than those described above. The hand-specimens are compact, dark-grey rocks, becoming grey-green upon weathering, and showing numerous veins and impregnations of white quartz, pyrites, and magnetite. The thin sections exhibit a dense, closely-woven mesh of minute, diverse, unorientated felspar laths (albite-oligoclase), with abundant small skeletal grains of iron-ore, chlorite, and an indeterminate grey

[1] The numbers within brackets refer to those of the specimens preserved in the Hunterian Museum, University of Glasgow.

material probably representing original pyroxene. There are also rare microphenocrysts of oligoclase, and occasional small patches of quartz, epidote, and chlorite. The quartz is undoubtedly secondary, and introduced at the same time as the quartz veins by which the rocks are penetrated. These rocks may be regarded as basic types of spilite intermediate between that rock and mugearite.

(2) *Soda-felsite.*—Two non-spherulitic felsites (C 14, C 15), which differ in no essentials from those described in a previous paper as quartz-felsite,[1] occur in the collection. The phenocrysts of quartz, albite, and orthoclase are perhaps less abundant, the groundmass finer-grained and more abundantly epidotized than in the formerly described specimens. These rocks greatly resemble the soda-felsite or soda-granite-porphyry of Porthallow Cove, Cornwall, which is also associated with a spilitic series.[2]

With the soda-felsites may be described a quartz-trachyte (C 20) from the same locality (Larsen Harbour). In thin section this rock shows numerous irregular areas of turbid, mottled, untwinned alkali-felspar, together with a few, elongated, simply twinned laths of sanidine, and irregular areas of quartz, in a groundmass consisting of minute, fluidally arranged laths of albite-oligoclase, a little orthoclase, and abundant interstitial quartz. The sanidine laths and large quartz areas are frequently invested by an irregular, discontinuous zone of cloudy alkali-felspar, which envelops the fluidal laths of the groundmass. While many of the constituent minerals are quite fresh and undecomposed, the rock is impregnated with irregular areas of epidote and particles of pyrites. This rock is clearly related to the soda-felsites, but differs in being less quartzose and in possessing a trachytic groundmass.

(3) *Greenstone* (*Albite-dolerite?*).—In hand-specimens these are fine-grained "greenstones" (C 5, C 6, C 7), all from Larsen Harbour, penetrated by quartzose veins, and impregnated with pyrites and quartz. One rock (C 6) shows numerous amygdales filled with greenish-black chlorite. In thin section the principal minerals shown are albite-oligoclase in thin laths, enclosed ophitically in masses of chlorite which doubtless represent original pyroxene. The felspar laths are often cloudy and mottled on account of minute inclusions of quartz, epidote, and chlorite. Ilmenite in process of alteration to leucoxene is an abundant constituent, and there is a considerable quantity of interstitial secondary quartz and epidote. A prominent feature in one of the rocks (C 6) is the occurrence of numerous, large, rounded vesicles filled with rosettes of yellow-green chlorite which shows in great perfection the characteristic ultra-blue polarization tints. C 5 is of finer grain than C 6, and is devoid of amygdales. C 7 has abundant secondary quartz and pyrites. These rocks are much decomposed greenstones, but enough is left of their original minerals and texture to establish the fact that they belong to the spilitic series, and were probably oligoclase or albite-dolerites similar to the types that accompany spilites in other regions.

(4) *Epidosite and other Vein Rocks.*—In the previous paper

[1] Geol. Mag., Dec. VI, Vol. III, pp. 438–9, 1916.

[2] *Geology of the Lizard and Meneage* (Mem. Geol. Surv.), 1912, p. 186; see pl. xii, fig. 6.

progressive epidotization of certain obscure igneous rocks was shown to occur, resulting, in its final stage, in the production of a rock composed mainly of epidote and quartz.[1] The same characteristic reactions are exemplified in the series of rocks now under description, with the addition that veins of epidotic material are now seen to be common. These are especially abundant in the spilites. Their average thickness is about 1 inch, but they may swell out to a width of 3 inches. They consist of a hard, dense, pale-yellow epidosite, containing irregular patches and segregations of greenish-black chlorite, and associated with a compact flint-hard, grey-green material. In thin section the epidosite appears extremely turbid, and is only translucent on the thinnest edges of sections, where it is seen to consist of an almost cryptocrystalline aggregate of epidote and silica. The grey-green flinty material is even denser. It is very feebly birefringent, and is irresolvable even under a $\frac{1}{6}$ in. objective. It carries tiny patches of epidote and quartz. The epidosite encloses irregularly-shaped areas which have a narrow border of granular epidote, or of epidote and quartz, with the remainder of the space filled with radiate masses of chlorite in which particles of leucoxene are enclosed. Smaller areas are filled with epidote and quartz, or with epidote alone, suggesting that the order of deposition has been first epidote, then quartz, and finally chlorite. The boundaries of the veins against the enclosing spilite are generally marked by a slight segregation of iron-ores within the rock.

Three specimens of massive epidosite occur in the collection (C 9, C 13, C 24), all from Larsen Harbour. They are hard, dense, splintery rocks of yellowish-green colour, which, in thin section, show an intimate granular admixture of epidote and quartz. As noted in the previous paper, the epidote grows euhedrally into the quartz wherever the latter mineral forms plates large enough for the relation to be observed. Chlorite, and pyrites in euhedral crystals, occur in varying amounts.

Quartz veins also occur abundantly in these rocks. In one specimen (C 18*b*) the rock (spilite) has been veined in all directions, leaving sharply angular fragments of country rock entirely surrounded by quartz. These fragments are highly silicified, as is also the rock adjacent to the sides of the veins. The quartz is very finely granular, except in some later veinules. Intermingled with the quartz are euhedral crystals of epidote and pyrites, with flakes of chlorite, and irregular masses of magnetite (strongly attracted by the bar magnet). In another specimen (C 25) the quartz is much coarser in grain, and in addition to the above-mentioned minerals also carries irregular patches of a translucent, reddish, optically isotropic ore-mineral, which is probably chromite. In C 18*a* there are curious, spherical, amygdale-like areas of very fine-grained quartz, which enclose sectors in which the quartz shows a concentric and radiate structure, as shown by the appearance of a black cross between crossed nicols. Other similar areas carry large euhedral crystals of pyrites. Still another shows a narrow border of minutely

[1] Geol. Mag., Dec. VI, Vol. III, pp. 439–40, 1916.

granular quartz, followed by a discontinuous zone of chlorite, with the interior of the cavity filled by coarsely granular quartz.

With these rocks may be described a fine, carnelian-red, jasper-rock (C 26—Larsen Harbour), which shows, in thin section, a groundmass of cryptocrystalline silica thickly impregnated by hæmatite in peculiar globular, clubbed, or roughly radiate forms, giving a texture which, after an obvious resemblance, may be called *amœboid*. The rock also carries large irregular masses of pyrites. This rock may represent the siliceous material often found associated with spilites, especially in the interstices between pillow-form masses.

2. Sedimentary Rocks.

The collection includes typical mudstones from King Haakon Harbour (C 3, C 4), with only the beginnings of cleavage. These rocks are penetrated by a great number of very thin, fine veins of quartz. From Gold Harbour there comes a fine-grained, banded greywacke (C 22), consisting of numerous thin alternations of arenaceous and argillaceous material. The interest of this rock is that it shows in a superlative degree the relative resistance of the two types of material to differential movement. The arenaceous bands show frilled and puckered folding; but in the adjacent argillaceous bands each pucker is represented by a line of strain-slip. As the argillaceous bands predominate, the rock, as a whole, splits easily along the strain-slip cleavage. Some of the arenaceous bands contain a few large crystals of quartz and albite, which are deformed, and in the case of the felspar sericitized, but which have nevertheless formed nuclei of resistance, causing the folds to pass round them. A similar rock has been described and figured in an earlier paper.[1]

Other rocks from King Haakon Harbour (C 1, C 2) are sheared crystal-tuffs with sporadic scapolitization, entirely similar to those described in a former paper.[2] They contain crystals of orthoclase and albite, and fragments of shale, as augen in a sheared, almost cryptocrystalline, groundmass, consisting apparently of sericitized felspar and chalcedonic silica. The scapolite occurs in compact, granular masses which appear to be pseudomorphs after rock-fragments, but the character of the latter is completely obliterated. The foliation is outlined by a wispy, greyish, argillaceous material the character of which cannot be determined. A considerable amount of pyrites has been introduced along the foliation planes.

A specimen from Gold Harbour (C 23) appears to have been a tuff, but has undergone much more advanced shearing than the rocks from King Haakon Harbour. Only a few remnants of quartz and felspar are left as augen, in a thoroughly foliated, granulitized paste of quartz and felspar, with filmy sericitic mica. Similar rocks from Gold Harbour were described in a former paper.[3]

3. Conclusions.

The most striking new fact afforded by the study of this collection of South Georgia rocks is the recognition of a spilitic

[1] "Petrography of South Georgia": Trans. Roy. Soc. Edin., vol. l, pt. iv, p. 826, pl. xciv, fig. 1, 1915. [2] Ibid., pp. 827–30.

[3] Geol. Mag., dec. VI, Vol. III, p. 436, 1916.

series of igneous rocks in and about Larsen Harbour at the south-eastern end of the island. The tectonic inferences to be drawn therefrom are so important that it was thought advisable to send the slides to Dr. J. S. Flett, F.R.S., for his opinion as to their spilitic nature. He has very kindly confirmed this identification. The diabases and melaphyres, described (macroscopically) by Heim, no doubt belong to this series. Furthermore, the epidotized lavaform and tuffaceous rocks of doubtful affinities, described by me in the last paper, almost certainly belong to the series.[1]

Associated with the dark-grey or grey-green spilites are light-coloured rocks which were previously identified as quartz-felsites. Dr. Flett prefers to call them soda-felsites; and this is undoubtedly the better term since the rocks are very rich in albite, and must be regarded as consanguineous with the albite-rich spilites. The alaskite from Cooper Island, described in the last paper, is perhaps also to be correlated with this series.

Furthermore, the badly decomposed rocks here described as greenstones were probably once dolerites with a sodic plagioclase, oligoclase or albite, petrographic types which elsewhere are closely associated with spilites and soda-felsites. The ophitic dolerite from Cumberland Bay and the epidiorite (meta-dolerite) of Gold Harbour, described in previous papers, are probably also to be associated with the spilitic series. These rocks, however, differ entirely from the ophitic dolerites and basalts from Larsen and Slosarczyk Harbours in the last collection.[2] The latter rocks are very fresh, with a much more calcic plagioclase than is general in the spilitic series, and furthermore have escaped the epidotization which is so characteristic of that suite. Hence it is believed that they belong to an intrusive series of much younger date than the spilitic series.

From consideration of the evidence now accumulated South Georgia consists principally of a folded sedimentary complex, including greywackes, slates, mudstones, and tuffs, of uncertain age, probably Palæozoic in the main, but perhaps ascending into the Mesozoic. It contains a spilitic series of igneous rocks at the south-eastern end of the island, and intrusive rocks of the same group occur within the sediments at least as far away as Cumberland Bay. Rising behind the dark, "altvulcanischer" region around Larsen and Drygalski Harbours, Heim saw a great, light-coloured massif, the composition of which was believed to be granito-dioritic from the evidence of the moraine material within the area.[3] The specimen of granite-porphyry collected by Mr. Ferguson from the glacial material at Moraine Fiord probably belongs to this or a similar complex.[4]

Spilites are characteristically associated with rocks of Palæozoic or Pre-Palæozoic age; and if this relation holds in South Georgia, the presence of spilites may be held to reinforce the view that the sedimentary series of the island is mainly of Palæozoic age. The

[1] Ibid., pp. 439–40.
[2] Ibid., p. 437.
[3] Op. cit., p. 454.
[4] Trans. Roy. Soc. Edin., vol. l, pt. iv, p. 830, 1915.

lithologically very similar sedimentary series of the South Orkneys is definitely known to be of Lower Palæozoic age (Silurian) from the evidence of graptolites.[1] It is a fact suggestive of close geological relationship between South Georgia and the South Orkneys that a small pebble of typical spilite was found by me in a series of rocks collected by the *Scotia* Expedition from Coronation Island in the South Orkneys.[2]

According to Dewey and Flett spilites are the characteristic volcanic rocks of districts that have been undergoing long-continued subsidence.[3] This relation receives further exemplification from South Georgia, where the sedimentary series is of great thickness and continuity, and lithologically is of shallow-water origin. Benson has shown that spilites are not necessarily indicative of deep-water conditions as supposed by Steinmann and others.[4] Lastly, attention may be drawn to the fact that the South Georgia sediments are radiolarian, another character often exhibited by the sedimentary rocks associated with a spilitic suite.

The existence of a spilitic suite in South Georgia and the South Orkneys has an important bearing upon the tectonic relations of these islands. The balance of evidence may now be said to tip definitely against Suess's interpretation of their structure. He believed that they formed part of a great eastwardly-directed loop, homologous with the Antilles, connecting the Patagonian Andes with the mountain ranges of Graham Land. The continued absence of typical Andean volcanic rocks in spite of repeated collection of the rocks of South Georgia, as well as the existence of a spilitic series, favours the interpretation that South Georgia and the South Orkneys are remnants of an ancient continental land which once occupied the South Atlantic.[5]

III.—Morphological Studies on the Echinoidea Holectypoida and their Allies.

By Herbert L. Hawkins, M.Sc., F.G.S., Lecturer in Geology, University College, Reading.

VIII. On *Pygastrides*, Lovén, a Problematical Holectypoid.

(PLATE XVII.)

1. Introduction.

It may be thought that some apology is due to the readers of this Magazine on the ground of the largely zoological bearing of this paper. But in the opinion of the writer no such apology is necessary. Zoology is palæontology brought up to date, and ontogeny is but a compressed and individualistic type of phylogeny; so that in spirit, though not in matter, this paper is no less appropriate for

[1] J. H. Pirie, Proc. Roy. Soc. Edin., vol. xxv, pp. 463–70, 1905.
[2] Op. cit. supra, p. 833.
[3] Op. cit., p. 242.
[4] W. N. Benson, "Spilite Lavas and Radiolarian Rocks of New South Wales": Geol. Mag., dec. V, Vol. X, pp. 17–21, 1913.
[5] J. W. Gregory, "The Geological Relations and some Fossils of South Georgia": Trans. Roy. Soc. Edin., vol. l, pt. iv, pp. 817–22, 1915.

publication here than its seven predecessors have been. According to Lovén himself, the minute Echinoid which supplies the text for the sequel is to be considered a survivor, not merely of the Holectypoida, but of the most primitive family of that Order—a kind of *Lingula* or *Nucula* among Irregular Echinoids. Although one of the main purposes of the following pages is to offer reasons for disbelieving that contention, nevertheless *Pygastrides*, as far as the only specimen known is concerned, is for all practical purposes primitively Holectypoid in essential characters. This seeming paradox may be resolved by the anticipatory remark that Lovén's so-called genus is believed to be an early post-larval stage in the development of some more completely Irregular adult form. It is ontogenetically related to that problematical adult, just as the Pygasteridæ must be phylogenetically ancestral to it.

At the time of its description by Lovén *Pygastrides* was almost the only developmental stage of its kind known. Now there are several comparable ontogenetic phases available for comparison, notably the gnathostomatous young of *Echinonëus cyclostomus* and the originally endocyclic early post-larval forms of *Abatus cavernosus* and *Echinocardium flavescens*. The three different ontogenetic lines thus indicated serve to prove conclusively the phylogenetic relationship of the Holectypoida to the Irregular Echinoids. Even if *Echinonëus* be considered to be an Holectypoid (and I incline to believe that it should be so classed), its affinities with other groups are many and manifest. *Pygastrides*, as the following arguments seek to show, must be a young stage of some other type of Irregular Echinoid, while *Abatus* is a Spatangid of the Spatangoids.

In the course of the discussion on the affinities of *Pygastrides*, certain morphogenetic points arise. These are mainly concerned with the perignathic girdle, so that this paper is in some respects a direct sequel to its three immediate predecessors. It was thought better to keep it distinct from them because, while they were based upon direct observation, the substratum on which the following arguments rest is theoretical, although it seems to me to be more secure than mere conjecture.

2. Résumé of the Characters of *Pygastrides relictus*.

In 1874 Lovén (*Études sur les Échinoidées*, p. 79), in a footnote to a description of certain "Echinoconidæ" (Holectypoida), mentioned the existence of a small recent form from the Caribbean Sea that he believed to be a living species of *Pygaster*. He gave it the *nomen nudum* of *Pygaster relictus*. After a delay of fourteen years, during which "the little thing" succeeded in avoiding capture, in spite of "most energetic exploration" of its habitat, Lovén gave a full and beautifully illustrated description of the solitary and imperfect specimen on which his previous comment had been bae d (1888, "On a Recent Form of the Echinoconidæ"). Detailed study of the small corona showed that it differed in many important respects from that of *Pygaster*, and caused Lovén to diagnose a new genus, *Pygastrides*, for its reception. *Pygastrides relictus* still remains unique, a sufficiently remarkable fact in view of the amount of

deep-sea exploration that has been achieved since 1888. Further discussion of its characters and affinities must needs be based on new knowledge of its alleged relatives.

The following is an abridged account of its salient features taken from Lovén's description :—

Length	3·5 mm.
Breadth	3·41 mm.
Height	2·16 mm. (0·62 of length).
Peristome diameter . . .	[1·015 mm.] (0·29 of length).

Corona.—Obscurely subpentagonal; tumid.

Apical system.—Wanting, apparently central in position.

Peristome.—Central, very slightly invaginated. Outline irregularly circular. The epistroma not extending quite to the margin, leaving a delicate inner rim in which occur narrow branchial (?) incisions. Interradial margins built of large, single primordial interambulacrals. Ambulacral margins built of high, narrow primordial ambulacrals. Externally each ambulacral bearing a large "epistromal prominence" with a glossy and minutely punctate surface, the pairs of these meeting adorally to a large, single, perradially situate sphæridial pit.

Perignathic girdle.—Paired ambulacral processes of slightly cuneiform shape, expanding distally, meeting the floor of the test at a very acute angle. The processes are apparently placed over the adradial sutures. The figure (Lovén, pl. i, fig. 5; here Pl. XVII, Fig. 2) is hard to understand. It gives the appearance of a specially intercalated plate as the foundation of each process, a most anomalous condition. Possibly the apparent sutures represent the raised edges of the articulation between the processes and the corona. There seem to be no interradial perignathic elements.

Periproct.—Mostly broken away, but apparently projecting into interambulacrum 5 almost to the ambitus. Posterior margin broad and symmetrical.

Ambulacra.—Composed of simple, rectilineal plates throughout. No biporous plates. (In Lovén, pl. i, fig. 5, the proximal ambulacral in column III*b* seems to show two pores; but this is in contradiction to the statements in the text, and is probably due to an error in drawing or printing.) Pore-pairs confluent, dissimilar; external pore round, internal pore slit-like; placed near the adapical transverse margins of the plates. Peripodia sunken.

Interambulacra.—Built of normal, mostly unituberculate plates. Proximal unpaired plate very large, variable in size and shape in the several areas. In Lovén's figure (here Pl. XVII, Fig. 2) plate 1*a*, 2, is shown to be low and cuneiform, tapering towards the interradial suture. Similarly placed plates in other areas tend towards this character.

Ornament.—Primary tubercles large, scrobiculate, crenulate, and with perforate mamelons. Approximately similar in size on interambulacra and ambulacra, and in both arranged in regular series. Surface of both areas thickly studded with glossy, ovoid protuberances, often grouped into scrobicular circles around the main tubercles.

Habitat.—Near Virgin Islands, between 200 and 300 fathoms.

3. Is *Pygastrides* an Holectypoid?

Ignoring the question discussed in section 4, it is a matter of considerable interest and importance to ascertain the systematic position which *Pygastrides* can occupy. There can be little doubt that Lovén was right in regarding the "genus" as one of the "Echinoconidæ", i.e. Holectypoida. His association of it with *Pygaster*, while still eminently reasonable, is not quite so inevitable. It would be difficult to locate it in any of the families of the Holectypoida as at present recognized—it combines certain characters that occur in all families of the order, and possesses some that are not found in any of them.

The Holectypoid qualities may be thus summarized:—The approximately radial symmetry of its outline; the central, circular, fairly large peristome with apparent "branchial incisions" and a perignathic girdle (hence presumably a lantern); the adapically situated periproct, apparently in contact with the apical system and not located in a sulcus; the non-petaloid podial pores; the serial arrangement of primary tubercles on both areas and their scrobiculate, crenulate, and perforate nature. Such an assemblage of characters, nearly all of a positive type, makes it impossible to regard *Pygastrides* as belonging to any order of Irregular Echinoids but the Holectypoida.

Nevertheless, there are certain features in *Pygastrides* which do not agree with the Holectypoid diagnosis. The perignathic girdle seems devoid of interradial elements; the ambulacra show no trace of "plate-crushing", particularly near the peristome, and their pores are conjugate and dissimilar, perforating the plates near the *adapical* margins; the sphæridia are single, deeply sunken, and perradial in position; the tubercles seem to be all primaries, and the granulation is peculiar. It might reasonably be argued that these (chiefly negative) differences are due to the small size of the specimen. But in examples of *Discoides dixoni* and *Conulus subrotundus* of scarcely greater dimensions the full Holectypoid requirements are fulfilled.

Pygastrides may, then, be considered as representing an Holectypoid in which certain features are lacking, and in which one set of structures, the sphæridia, is apparently abnormally situated. The disposition of the sphæridia in the fossil Holectypoida is not yet known with certainty; they were presumably not deeply sunken; but in *Echinonëus* they occur *on* the ambulacral plates, superficially placed, and to the number of three or four in each area.

In an attempt to trace the affinity of *Pygastrides* with any of the families of the Holectypoida less definite evidence appears. To the Pygasteridæ (and especially to *Plesiechinus*) it is similar in symmetry, peristome (save for the smallness of the branchial incisions), perignathic processes (apart from their angle of setting and the lack of buttresses), periproct, and tuberculation. The simplicity of its ambulacral plating, though too complete, is another link with this primitive family. *Pygastrides* resembles the Discoidiinæ in the relatively large size of the primordial coronal plates and in the feeble development of the branchial incisions. The peculiar structure of the interambulacra near the peristome is extraordinarily like that contiguous to the "false ridges" of *Discoides*. It suggests that the

primordial interambulacral plates block the path of the advancing columns, giving a type of "plate-crushing" comparable with that described by me in *Lovenia forbesi*. The minor ornament of the test is suggestive of some of the guttate granules of *Holectypus depressus*, and perhaps of the glossy granulation of the adoral surface of *Conulus*.

Thus, while showing a preponderance of Pygasterid characters, *Pygastrides* exhibits important differences from the known members of that family, combining in the one small corona qualities that are shared among all the families of the Holectypoida, and especially suggesting some affinity with the Discoidiinæ. It may be defined as a generalized Holectypoid with mainly primitive traits.

Finally, there is one feature in which *Pygastrides* probably differs from the normal Holectypoida and is certainly different from their nearest living representatives. It is a deep-water form. Although it is difficult to speak with certainty on the bathymetric range of fossil types, all the evidence seems to show that the Pygasteridæ (to which *Pygastrides* makes the closest approximation) were essentially denizens of shallow water. The latest Pygasterids, such as *Anorthopygus*, are only known from the littoral facies of the Chalk-sea deposits (e.g. the Hibernian Greensand and the Haldon Hill remanié), never being found in the regions of open-water ooze. *Echinonëus* abounds chiefly between tide-marks, and *Micropetalon* is not known from a greater depth than 24 fathoms. Possibly some of the Cretaceous Holectypoida, such as *Conulus albogalerus*, may have inhabited water of considerable depth, but there is no proof that they lived at such a depth as 250 fathoms. Moreover, they are morphologically the least like *Pygastrides* of any members of the order. This point, though of little systematic value by itself, is worth noting in conjunction with the other divergences of *Pygastrides* from the Holectypoid type.

4. Is *Pygastrides* Adult, or a Post-Larval Stage?

It follows from the discussion in the preceding section that *Pygastrides*, if it be a genuine genus, must find a place among the Holectypoida, although the diagnosis of the Order would need some modification for its inclusion. As at present known, it cannot possibly be associated with any other order of Echinoids.

Lovén seems to have been convinced that this small specimen is adult. He supported his contention by reference to the "rather thick" and rigid test, the character of the tubercles and epistromal prominences, and the depressed ambulacrals. He further remarked that, were it larger when adult, specimens would hardly have escaped capture. This last contention may be dismissed at once, since it is based upon the assumption that the adult form would closely resemble the small specimen. It does not follow that, supposing *P. relictus* to be an ontogenetic phase, the adult is not already known, the correlation of the two being at present impossible. Zoologists are painfully aware of the difficulty of identifying a larval stage with its adult form, even when both are fairly abundant. It is reasonable to suppose that, if *P. relictus* is a young stage, its adult equivalent has already been discovered.

As Lovén admitted, it is difficult to derive satisfactory evidence of the age of *Pygastrides* owing to the absence of the apical system, but to my mind the indirect evidence that indicates its immaturity is conclusive.

In point of size *P. relictus* is far smaller than any known adult Echinoid, fossil or recent. Lovén (Études, p. 79), regarding it as a Cretaceous survival, remarks, "La plupart des formes crétacées retrouvées vivantes a de grandes profondeurs sont comparativement petites." But *Pygastrides* is not "comparativement", it is "absolument petit". In the paper devoted to this problematical Echinoid Lovén admits that "Littleness . . . seems to be another character by which it departs . . . from the recent forms among which it lives". The minute size, though not conclusive, is strong presumptive evidence for youth.

In the absence of definite measurements of the thickness of the test, it is difficult to frame an opinion on the value of Lovén's description "rather thick". There is no evidence that young Echinoids of as much as 3·5 mm. diameter are so little calcified as to undergo shrivelling when dried— a quality that Lovén apparently would have expected in *Pygastrides* were it truly neanic. *Echinonëus cyclostomus* seems to have a perfectly rigid corona when it has attained comparable dimensions, and certainly *Parechinus miliaris* is quite massive at that size.

Since *P. relictus* is an Irregular Echinoid, the tubercles, which Lovén cites as showing no specially youthful characters, are certainly disproportionately large, and remarkably sparse. They compare well with those of *Abatus cavernosus* (see Pl. XVII. Fig. 5), 2·5 mm. in diameter, as figured by Mortensen (Schwed. Südpolar. Exped.). They are considerably larger in proportion to the size of the test than in any adult Holectypoid, and even than in examples of *Plesiechinus ornatus* of less than 8 mm. in diameter. Since the tubercles of the Holectypoida are larger than those of other Irregular orders (excepting the specialized ones in some Heart Urchins), and they are constantly of fair dimensions in the relatively more primitive Regular Echinoids, their large proportions in *Pygastrides* certainly suggest that youthfulness is the cause.

So little is known of the early post-larval stages of many groups of Echinoids that the character of the "epistromal protuberances" can hardly be used as a criterion of age. There are plenty of granules and glassy tubercles on *Echinonëus* when the diameter is only 4 mm.

Reference to the ambulacral plates of *P. relictus* seems to me to afford more indication of youth than of maturity. It is true that, with the exception of the primordial plates of the columns, the ambulacrals are all "Cidaroid" in character; but they are not lower than those of *Echinonëus* at 3·7 mm. diameter. Moreover, if *Pygastrides* is an Holectypoid, and an adult one, it is unique in the order in having no suspicion of "plate-crushing". In the small gnathostomatous *Echinonëus* of about the same size there are already demi-plates in the ambulacra, and in specimens of *Plesiechinus ornatus* not exceeding 5 mm. in diameter some of the plates are

already distorted. Thus the extreme simplicity of the ambulacral plating is again suggestive of youth.

Other features in *P. relictus* which are concordant with the view that it is a young form are: (1) the great size of the proximal coronal plates, (2) the general rotundity of the test, and (3) the relatively large size of the sphæridia.

The position of the periproct gives little help in this discussion. Certainly, if *Pygastrides* were adult, it would prove to be the least progressive of all known living Irregular Echinoids in this respect (excluding perhaps "*Nucleolites*" *recens*), being no more advanced than the Lower Jurassic *Plesiechinus*. But even so advanced a Spatangoid as *Abatus cavernosus* (Pl. XVII, Fig. 5) has the periproct on the adapical surface and in contact with the apical system when it has attained a diameter of 2·5 mm., while at 1·9 mm. it is definitely endocyclic. A less specialized Irregular Echinoid might well have a "Plesiechinoid" periproct when it had reached the dimensions of *Pygastrides*.

As a result of the considerations put forward above, I am convinced that *Pygastrides relictus* is an early post-larval form of some larger species, the adult stage being, in all probability, some type of Irregular Echinoid already known.

5. Comparison of *Pygastrides* with *Echinonëus* of the same size.

For the purpose of this comparison I have relied upon Westergren's beautiful drawings (1911, Mem. Mus. Comp. Zool. Harvard, vol. xxxix, No. 2, pl. xi).

The corona of *Pygastrides* is more circular in outline and more elevated than that of *Echinonëus* at 3·7 mm. diameter.

The peristomes of the two forms are similar in proportion and shape, but in *Echinonëus* the primordial coronal plates are considerably reduced in size. There are three sphæridia in each ambulacrum in *Echinonëus*, in contrast to the single one in *Pygastrides*.

The perignathic girdle is in a far higher degree of development in *Pygastrides* than in *Echinonëus*, and the processes are only partly based upon the ambulacral plates.

The periproct of *Echinonëus* has already reached its adoral situation at this stage of development—a marked advance on its condition in *Pygastrides*.

The ambulacra of *Echinonëus* have the primordial plates not strikingly dissimilar from the rest, while in *Pygastrides* these plates are very high. Demi-plates occur already in the former type, while there seems to be no trace of disturbance in the regularity of the shape of the ambulacrals in the latter. The pores of *Echinonëus* are round, disjunct, and normally situated in oblique pairs on the more adoral parts of the plates—the reverse is the case in *Pygastrides*.

In the interambulacra a similar relation of the primordial unpaired plates exists to that found in the ambulacra.

The tuberculation of *Echinonëus* at 4·4 mm. is closely comparable with that of *Pygastrides*.

The young forms of *Echinonëus* occur between tide-marks with the adults, while *Pygastrides* was dredged from deep water.

An analysis of the above comparison shows one feature of great significance. In practically every quality in which the two forms differ *Pygastrides* proves to be the less advanced from the Regular (or better, Pygasterid) condition. It is, like *Plesiechinus*, a Regular Echinoid save for the (incomplete) posterior migration of the periproct. Thus, if it really is a young stage, it must be affiliated to some species that is less remote from a primitively Holectypoid condition than *Echinonëus*. At least, *Pygastrides* cannot be a stage in the development of that genus.

6. The Probable Adult of *Pygastrides*.

One of the most obvious qualities in the structure of *Pygastrides* is the position of the sphæridia. These are single, and placed in considerable depressions on the perradial lines. This is in complete contrast to their disposition in *Echinonëus* (and probably in the fossil Holectypoida), and in the Cassidulidæ and Spatangidæ. It compares with their arrangement in Regular Echinoids, but such comparison is vitiated by the undoubtedly Irregular affinities of *Pygastrides*. The only groups of Irregular Echinoids which possess single, perradially situate sphæridia are the three Clypeastroid families of the Fibulariidæ, Laganidæ, and Scutellidæ. In them, the sphæridia are deeply sunken, and in some cases entirely buried, in the test-surface; the sphæridial pits of *Pygastrides* are unusually deep. Unless it can be shown that sphæridia are capable of migration during ontogeny (a most improbable occurrence), it must be assumed that the adult stage of *Pygastrides* has deeply sunken, perradial sphæridia. These need not of necessity be single, since new sphæridia might be developed with advancing age; but among the known adult Irregular Echinoids that have median sphæridia, they seem to be always solitary. This evidence, then, limits the choice of an adult for *Pygastrides* to three families of the Clypeastroida, and I cannot imagine that it is deceptive.

Turning now to the proportions of the proximal coronal plates: their great size in comparison with the others is at once apparent. They form a strong, broad border to the peristome, strikingly unlike the condition prevalent among most Echinoids. The superficial resemblance of this primordial cycle to the perignathic structures of *Discoides* has already been noted—it is doubtful whether a true morphological correspondence exists. The elongated ambulacrals are reminiscent of those adoral to the phyllodes in the Cassiduloida, while the irregularity of the interambulacrals enhances the resemblance. Indeed, apart from the presence of a perignathic girdle and the position of the sphæridia, the peristomial parts of the corona of *Pygastrides* might easily change into a truly Cassiduloid pattern. The processes might be vestigial structures, destined for resorption as in *Echinonëus*, but the singleness of the sphæridia seems a fatal bar to the maintenance of the comparison.

Again, the proximal coronals of *Pygastrides* are closely similar to those of *Echinocyamus* (Pl. XVII, Fig. 4), a small genus that retains throughout life many primitive Clypeastroid features. For example,

the corresponding plates of an *Echinarachnius* of 6·5 mm. diameter (about twice that of *Pygastrides*), figured by Lovén (Études, pl. i, fig. 245), are practically identical in proportions with those of *Echinocyamus*. In the Clypeastroids, however, the succeeding ambulacral plates are high and hexagonal, unlike the "Cidaroid" ambulacrals of *Pygastrides*. Since all coronal plates undergo considerable changes in size, and often in shape, during the growth of the test, this difficulty, though real, is not insurmountable. The "Bothriocidaroid" character of the extra-petaloid ambulacrals of the Clypeastroids is a sign of their obsolescence—they would hardly be in that condition when first developed.

The globular form of *Pygastrides* makes it difficult to suppose that it would develop into a discoid Scutellid, although such a change would be by no means impossible. However, most of the Fibulariidæ, especially *Fibularia* itself, have elevated tests that do not differ seriously in their proportions from those of *Pygastrides*.

The peculiar multiporous plates of the ambulacra of the Fibulariidæ are certainly very different from those of *Pygastrides*, but there are indications of disturbance in the latter. The anomalous nature of the pore-pairs, with a round *internal* pore, and their position near the adapical margins of the plates, seem to indicate some aberrant development. The rows of pores on the Fibulariid ambulacrals are similarly placed.

A review of the above arguments gives the following conclusions. The position of the sphæridia, if it be a reliable character, points definitely to the Fibulariid, Laganid, or Scutellid nature of the adult of *Pygastrides*. The relations of the proximal coronal plates do not carry the argument much further, but they are generally Clypeastroid in character, with some resemblances to the Cassiduloid quality. The general shape of the corona is more suggestive of a Fibulariid than of any other likely adult. So that the balance of evidence tends to indicate that *Pygastrides* is an early post-larval stage of some such genus as *Fibularia*. The characters of the perignathic girdle are not antagonistic to such a conclusion (see section 7), but the nature of the ambulacra introduces a difficulty. In *Echinocyamus* and its allies, the extra-petaloid ambulacrals are high, and each plate is perforated by numerous minute pores arranged, for the most part, transversely near the adapical suture. This extremely specialized, perhaps degenerate, condition must have been derived phylogenetically from a more normal biporous state, and there is every reason to expect that such a change would be repeated in ontogeny. The features in which the podial pores of *Pygastrides* are aberrant all point towards a Fibulariid modification more than to any other.

I therefore incline strongly to the opinion that *Pygastrides relictus* is an early phase in the post-larval ontogeny of some species of the Fibulariidæ. The conclusion reached at the close of the previous section—that *Pygastrides* is a young stage of some form less remote from the primitive Holectypoid condition than *Echinonëus*—is thus concordant with the result of this independent line of argument.

7. The Morphogeny of the Clypeastroid Perignathic Girdle.

There are two strikingly different types of girdle-structure in the Clypeastroida. In the Fibulariidæ, Laganidæ, and Scutellidæ the "auricles" are situated on the proximal interambulacral plates. In the rest more normal paired processes rise from the proximal ambulacrals. In one respect, however, there is a resemblance between these different structures; there is in all a strong tendency for the prominences to converge towards the interradii. In the Clypeastridæ the great development of the proximal ambulacrals, which often meet across the interambulacral, makes such a tendency possible without a dissociation of the processes from their normal foundations. But in the three families named above the proximal interambulacrals are present in unusually large development on the peristomial margin, so that no appreciable convergence of the processes would be possible if they remained on the ambulacrals.

H. L. Clark has proved that the apparently single interradial "auricles" of the Fibulariid type are in reality double in origin and intimate structure—they are, in fact, dislocated processes which have carried their attempt at interradial convergence to the extreme limit. In the preceding paper of this series I showed how both types of Clypeastroid girdle could be derived from the Holectypoid type. *Pygastrides*, if its ascription to the Fibulariidæ is correct, gives an ontogenetic stage in the migration of the processes from the ambulacra to the interambulacra. The obscurity of Lovén's figure in this respect is unfortunate, but it is sufficiently intelligible to show that the processes are as much on the interambulacra as on the ambulacra. Pl. XVII, Figs. 7*a*, *b*, *c*, show in a diagrammatic fashion the possible stages through which this change might be brought about. As to the persistence of an interradial element (ridge) carrying the protractor muscles there is, at present, no evidence in either direction.

Pygastrides affords a valuable simplification to the problem of the derivation of the Clypeastroid girdle from the Holectypoid. Granting the very near relationship between the Clypeastroida and *Discoides*, the difference between their perignathic structure is somewhat embarrassing. But if they pass through a *Pygastrides*-phase, which is simpler in some respects even than that of *Pygaster*, the girdles of the Fibulariid and Clypeastrid patterns need not be encumbered by the massive false-ridges of *Discoides*. The ontogenetic repetition preserves the essentials, and entirely leaves out the individual specializations of the ancestral adults.

In this respect it is noteworthy that both *Pygastrides* and the young *Echinonëus* are entirely without interradial ridges. In the case of the latter, the protractor muscles are fixed to the free edges of the proximal interambulacrals; these being, so far as appears, quite unmodified as special muscle-supports. In the fossil Holectypoida, as I have shown in this series of papers, there is always some small relic of an interradial ridge on the proximal interambulacrals, minute though these plates usually are. It may well be that the absence of these structures in the two young stages is due solely to their youth—they never appear in the edentulous

Echinonëus, but at least the muscle scars develop later in *Echinocyamus*. In the Clypeastridæ, again, no interradial elements occur, the protractor muscles finding attachment on the processes themselves.

The Fibulariidæ and Laganidæ are certainly less specialized in most characters than the Clypeastridæ. It is therefore strange to find the fused interambulacral processes—a highly specialized condition—occurring in the former groups, while more typically Holectypoid qualities are preserved in the latter. But if the theoretical structure of the "auricle" of *Echinocyamus* given on Pl. XVII, Fig. 7*c*, is in any way correct, that type of girdle is more closely akin to the Holectypoid (especially to the Discoidiid) type than the ridgeless girdle of *Clypeaster*. The two types of Clypeastroid girdle must, however, mark two distinct and divergent lines of descent; in one all structures become ultimately interambulacral, in the other ambulacral, in position. Both types differ from the true Holectypoid, and it is premature to ascribe greater or less specialization to either.

8. The Bearing of *Pygastrides* on Post-Holectypoid Phylogeny.

It will be realized from the foregoing descriptions and arguments that *Pygastrides* is in most respects an Holectypoid, in many a Pygasterid, in some a Discoidiid, and is probably the young of a primitive Clypeastroid. Of the young *Echinonëus* of similar size it may with equal justice be said that it is in most respects an Holectypoid, in many a Pyrinid (or Conulid), and in some a Discoidiid. The young *Abatus* at a smaller size may be said to be Pygasterid in apical and periproctal characters, Pyrinid in shape, but already Spatangid in coronal plating. The last-named form is evidently so accelerated in its ontogeny that no certain conclusions can be drawn without more evidence. The two others are more restrained in development, and their evidence on the phylogeny of their adults is intelligible and conclusive. Of *Echinonëus* and its relatives I hope to treat in the near future, but it will suffice here to incorporate the evidence of *Pygastrides* into the scheme of post-Holectypoid evolution.

Palæontological and morphological study link the Clypeastroida inseparably with the Holectypoida. The peculiar distribution of the madreporic pores and the development of internal supports associate them more particularly with the Discoidiinæ. Whether *Echinocyamus* and its relatives be primitive or degenerate, they are certainly the simplest of the Clypeastroida. *Pygastrides*, if the above interpretation of its nature is correct, adds a conclusive ontogenetic proof of the near alliance between the two orders, and suggests that the Fibulariidæ are truly primitive. Almost the only features in which *Pygastrides* differs from a true Holectypoid consist in the omission of certain structures, most of which are obsolescent in the Holectypoida themselves.

9. Summary.

Pygastrides relictus, Lovén, is believed to be an early post-larval stage in the development of some Irregular Echinoid. Reasons are

given for the belief that this Echinoid is probably a Clypeastroid, and one of the Fibulariidæ. In view of its undoubted resemblance to the Holectypoida, particularly to the Pygasteridæ and Discoidiidæ, *Pygastrides* is regarded as affording ontogenetic evidence of the phyletic connection of the Clypeastroida and Holectypoida through the Discoidiidæ.

EXPLANATION OF PLATE XVII.

FIG.

1.—External view of the peristomial region of *Pygastrides relictus*, much magnified (after Lovén).

2.—Internal view of the same region. The perignathic processes are broken away in areas I*b*, IV*a*, and V*a*.

3.—Proximal end of an ambulacrum of a Scutellid (*Encope*), showing the single, perradial, deeply sunken sphæridial pit (after Lovén).

4.—Plan of the peristomial region of the corona of *Echinocyamus*, internal surface. The ambulacra are stippled. (Reversed and modified from Lovén so as to compare with Fig. 2.)

5.—Adapical view of young *Abatus cavernosus*, 2·5 mm. in diameter (after Mortensen). The periproct is Plesiechinoid in position, and the apical system Pygasterid in character.

6.—Internal view of the peristomial region of young *Echinonëus*, 4·19 mm. long (after Westergren). Note the reduced proximal plates and the progressive ambulacral structure.

7.—Diagrams to suggest the possible origin of the Fibulariid "auricle". The ambulacra are stippled. (*a*) Disjunct processes of *Pygaster* or *Pygastrides*. Retractor muscles single, protractors on edge of proximal interambulacral plate, with or without a rudimentary ridge. (*b*) Processes meeting across interradius, and based upon the interambulacral plate. Retractor muscles double, protractors on a raised (Holectypoid) ridge. (*c*) Auricle of *Echinocyamus*. The dotted lines indicate its possible origin from stage *b*.

IV.—The Basic Intrusions East of Gelli Hill, Radnorshire.

By H. G. Smith, A.R.C.S., B.Sc., F.G.S.; with three analyses by J. H. Williams.

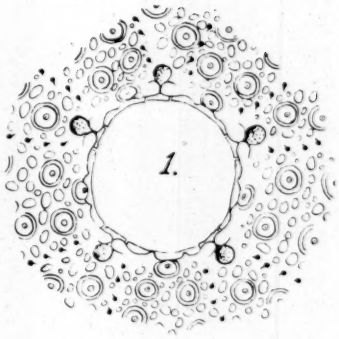
(PLATES XVIII AND XIX.)

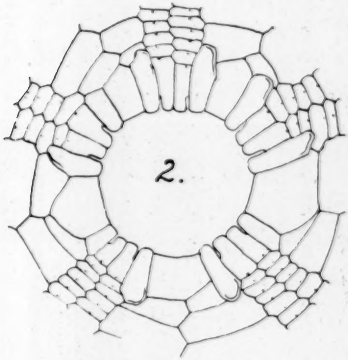
DURING the last few years I have spent a considerable amount of time studying the geology of the country east of Llandrindod, but much still remains to be done, and the present paper merely embodies a few of the points which seem to be satisfactorily established with regard to a small portion of the area. Three distinct types of igneous rocks are recognized, and some facts and ideas with regard to each are put forward.

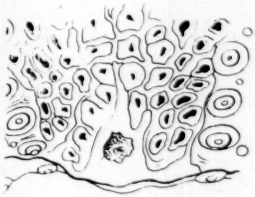
The Olivine Basalt.

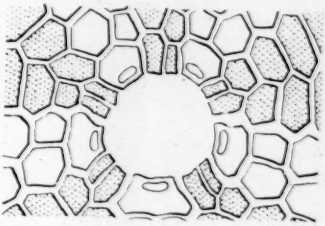
Forming part of the N.N.E.–S.S.W. ridge east of Tyn-y-coed, and best exposed in a quarry at its southern end, is a dark-coloured, almost black, fine-grained igneous rock, which, in the absence of any published descriptions,[1] calls for some comment. The same type also occurs about a mile to the north in the neighbourhood of Bwlch-

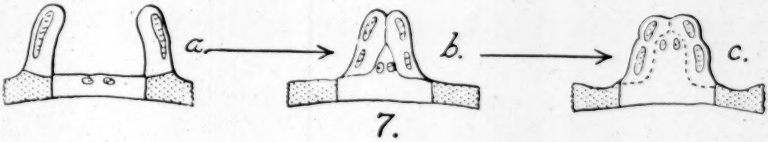
[1] Dr. Harker (Presidential Address to the Geological Society, Q.J.G.S., pt. i, 1917) mentions the existence of basalts in the Wells country, and considers them to be extrusive.

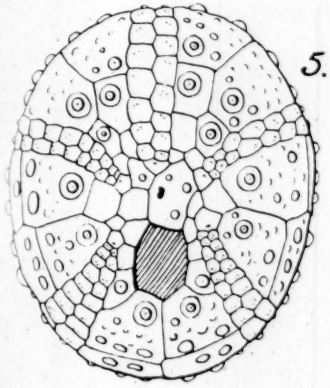


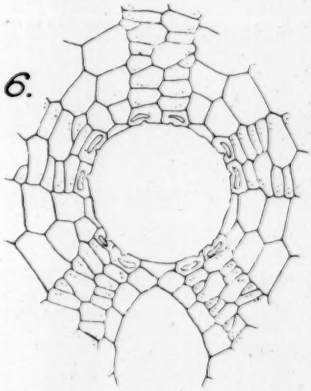












H. L. Hawkins del.

POST-LARVAL STAGES IN CERTAIN IRREGULAR ECHINOIDEA.

llwyn, notably forming a conspicuous elevation west of the Bog Wood. The specific gravity of the fresh variety is 2·86.

Examined microscopically, the rock is seen to be a typical olivine basalt with remarkably fresh felspar and augite. The most abundant constituent is the lath-shaped felspar, the crystals of which reach a maximum of 1·4 mm.; there is no indication of two generations. In some cases there is an aggregation into groups, producing a structure with some resemblance to glomero-porphyritic. The refractive index is well above that of Canada balsam, and some individuals are partially replaced by a green substance, probably clinozoisite. Between crossed nicols the felspar exhibits the usual first order colours and lamellar twinning, and the angle of extinction is rather high. Some zoning is to be seen. The refractive index and extinctions indicate a composition approximating to that of labradorite.

A very pale, almost colourless, granular augite occurs between the felspars. It has the usual relief; a few fragments exhibit the rectangular cleavages, and it is commonly quite fresh. The polarization colours are of the first and second orders.

There are occasional pseudomorphs, maximum dimension 1·2 mm., preserved in some cases in a pleochroic serpentine, elsewhere in a mixture of serpentine and calcite or quartz. Their shape and structure leave no doubt as to their derivation; they were originally olivine.

Ilmenite occurs moulded on the felspar; it is sometimes fresh, but the numerous grains of sphene present in the rock have probably resulted from its alteration.

A devitrified glass occurs as a groundmass. Some vesicles are filled with similar material, which exhibits a system of black crosses in polarized light. One vesicle is occupied by an almost isotropic glass with a curious cellular structure, the cells in places near the margin elongating to tubes with approximately radial disposition. This structure appears to be a record of the infilling of the vesicle, the various streams of viscous magma having failed to amalgamate after entry.

The observed occurrences of the basalt are all at or near a junction where fossiliferous felspathic ashes rest on shales with tuning-fork graptolites; hence the obvious conclusion that this rock represents the first product of the extrusive igneous activity responsible for the thick overlying ashes. But in spite of the fact that no metamorphic phenomena have yet been observed, its intrusive character is still considered to be a possibility. An Ordovician flow of this character would be absolutely unique in the igneous history of Wales,[1] and the rock is remarkably fresh. On this question of possible intrusion the suggestion made by Professor Watts[2] that the area of Tertiary igneous activity outlined by Dr. Harker[3] may have to be extended to the south has a possible application to this locality.

[1] W. G. Fearnsides, *Geology in the Field*, 1910, p. 801.
[2] Proc. Geol. Assoc., vol. xix. p. 179, 1905.
[3] *Tertiary Igneous Rocks of Skye* (Mem. Geol. Surv.), 1904, p. 3.

The Diabase.

This type makes an imposing show on the ground. One sill (aligned with the Castle Bank intrusion described by Mr. Woods[1]) commences just north of Camnant Brook, runs north-east between Blaenkerry and Garn-fach, turns due north, and is continued on the eastern side of Gelli Hill to disappear under the ashes near the Bog, a distance of about two miles. The Llanvirn Shales are in contact throughout most of this distance. Another intrusion is exposed north of Frank's Bridge. It runs N.N.E. for about a mile and stops short before reaching the River Edw. The same line is continued on the other side of the river at Graig-fawr, exposed as a sill dipping west, running just on the western side of the farm, and dying away in the vicinity of Llanwefr Pool. The northern part of the sill is shifted to the east by a dip fault. A shorter intrusion with the same trend is found west of Pye Corner, and, finally, a parallel sill runs from Cwm-maerdy to the Edw south of Pye Corner, but a portion of the sill is shifted to the east by trough faulting. The behaviour of some of these intrusions on approaching the rivers suggests that the serrated upper edges of the sills have not yet been obliterated, and the rivers have selected those places where the sinuous edge makes a downward bend.

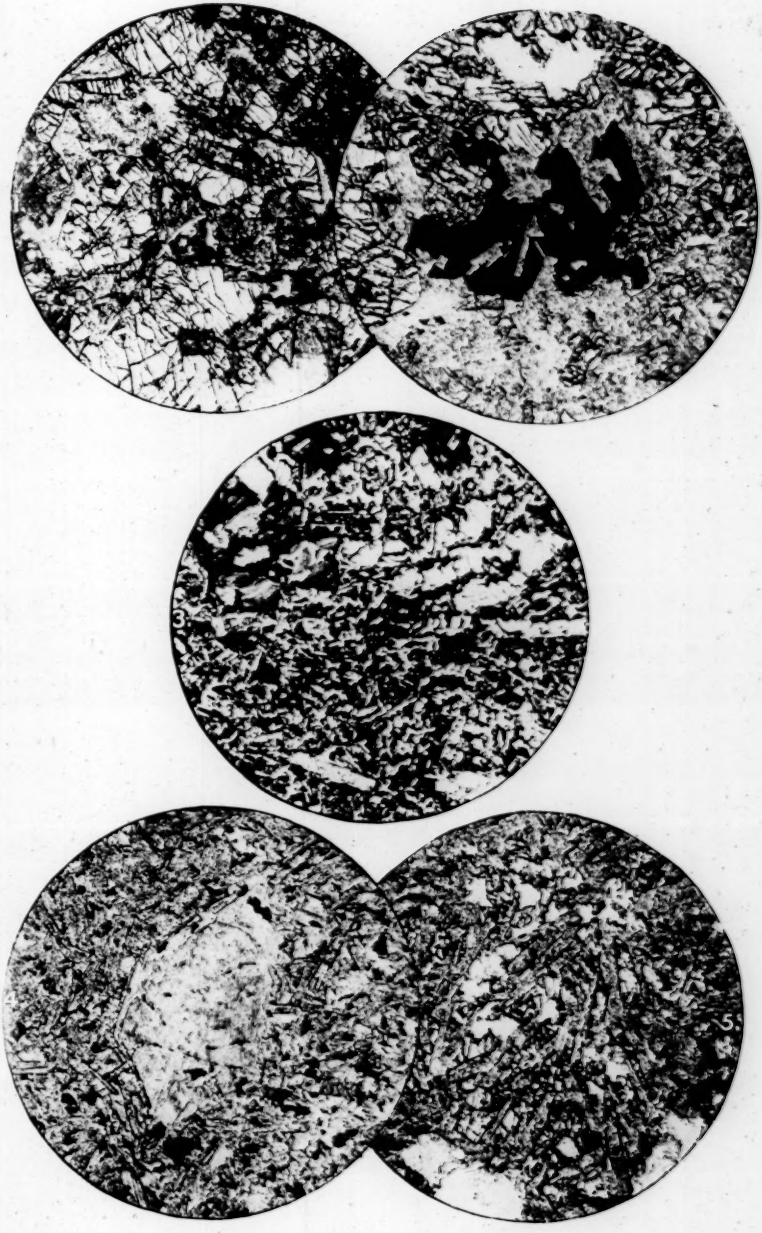
The rock is medium-grained with a general greenish tinge, showing a pale-grey network on a black background.

In thin section the rock is seen to be made up principally of pale-brown augite and lath-shaped felspars related ophitically. No fresh specimens have been obtained, and in all the sections examined the felspar is more or less decomposed; but as far as can be determined the refractive index is never high enough for labradorite, and this impression is supported by the symmetrical extinction angles of the albite lamellæ; the maximum value obtained is 16°, and it is suggested that the felspar is andesine. Pericline twinning is rare, and zoning has not been observed.

The augite varies from colourless to a pale brown. It has the usual refractive index and cleavages, and alters, as a rule, to chlorite, which polarizes in ultra-blue or first order grey, but in one section a brown amphibole represents an intermediate stage in the alteration. There is an occasional suggestion of pleochroism. The polarization colours are of the first and second orders, and twinning, though seen, is rare; the double refraction is positive. The individuals polarizing in very low colours are invariably found to be approximately perpendicular to an optic axis, and for this reason it is considered that the fresh pyroxene is exclusively monoclinic. There are, however, some pseudomorphs which show good cleavage, polarize in bright colours, and extinguish as a single unit which may be altered hypersthene. Some of the pseudomorphs suggest derivation from olivine, but proof is wanting.

Another constituent locally abundant is ilmenite. It commonly shows the characteristic white alteration product and is moulded on the felspar and augite. A few idiomorphic crystals of sphene

[1] Q.J.G.S., vol. l, p. 576, 1894.



Basic Intrusions in Radnorshire.

embedded in chlorite are possibly the result of the further alteration of this mineral. Acicular apatite is present in small quantity.

The amount of metamorphism effected by the diabase is never great, the most striking result being a rock resembling a spilosite, produced in consequence of the alteration of the shales which almost invariably occur at the contact. At one point, however, in the brook just south of Pye Corner the contact rock is a limestone containing fossils which Dr. Morley Davies recognizes as *Stricklandinia lirata* (Sowerby), *S. lens* (Sowerby), *Strophonella euglypha* (Sowerby), *Atrypa* sp., *Encrinurus* sp., and *Halysites* sp. This fauna he considers to be sufficient to prove the Upper Llandovery age of the sediment, and it therefore becomes a matter of extreme importance to determine the relative ages of intrusion and limestone.

A specimen of the diabase from near the contact includes a patch of calcite, which mineral is seen in thin section to be interstitial with regard to the felspars. The latter are not more basic than in the diabase remote from the limestone, but apatite is distinctly more abundant.

The limestone varies from pale grey to black. In places it exhibits some resemblance to a conglomerate, containing subangular fragments of quartz. Occasionally on the bedding plane is seen a spheroidal projection which, broken across, is not to be distinguished from the adjacent igneous rock, and similar igneous material is interbedded with the limestone, sometimes with a layer of crystalline calcite at the contact. Lenticles of calcite occur within the igneous material and patches of the igneous rock within the limestone. Some pyrite occurs at and near the junction. A thin section through one of the igneous spheres shows a diabase exactly comparable with that of the adjacent sill; the felspars interlock in the usual way and enclose angular patches of chlorite, and idiomorphic crystals of apatite occur in the felspar. The margin of the sphere is sharply defined; there is no transition into the limestone and, at this contact, there is no evidence of recrystallization of the latter.

The part of the rock not obviously igneous in origin exhibits features of considerable interest. Some portions of the sections are made up of a network of felspar crystals related just as in the igneous rock, but instead of interstitial augite or chlorite there is crystalline calcite. Here again the felspars are not more basic than in the diabase, and there is no support for the idea that calcareous material has been incorporated by the felspars. Other crystals of felspar appear to be isolated; they are sometimes idiomorphic, but elsewhere are moulded on the calcite. Quartz, either as simple individuals or as aggregates, occurs scattered through the rock as subangular equidimensional grains, as extremely angular individuals of various shapes, and as idiomorphic crystals. In one particularly interesting case the felspar and quartz are intergrown to form excellent micrographic structure. This example is sufficient to demonstrate the igneous origin of some of the quartz in the limestone and to render it extremely probable that no detrital quartz is present in the rock.

There is no question as to the relative ages of the two rocks; the

intrusion is certainly post-Llandovery. But there remains the interesting question as to why the diabase has failed to cut through the limestone. We are compelled to suppose that a magma exercises a careful selection [1] with regard to the rock invaded. In the case here considered the diabase magma readily penetrated the shales, but the overlying limestone presented an almost impassable barrier. Igneous material was injected along the bedding planes, and pockets containing the diabase were formed in consequence of a boring action on the part of the magma, while the areas occupied by a network of felspar with interstitial calcite resulted from the intrusion of a felspathic portion of the magma into a locally fused limestone area and subsequent crystallization of felspar followed by that of calcite.

All the evidence supports the theory that the diabase, when intruded into its present position, was nearing the limit of its powers of penetration. The still existing serrations of the upper edges of the sills, the failure to cut through the limestone, the very feeble metamorphism, and the fact that the silicates do not incorporate any of the calcium from the adjacent or containing limestone, all point in the same direction.

The conclusion here arrived at as to the age of the diabase is in direct opposition to that put forward by Mr. Woods [2] as a result of his examination of the area to the south. He relies on the facts that "nowhere do they (the diabases) pierce the Silurian beds", and that at "the section exposed in the quarry next Pen-cerig Lake, where the diabase is seen in contact with both Llandeilo shales and the Llandovery beds, the former are metamorphosed, the latter quite unaltered". But we have seen reason to suppose that failure to cut through a sediment is no proof that intrusion took place before that rock was laid down, and it follows from the facts put forward that striking metamorphic effects are not to be expected.

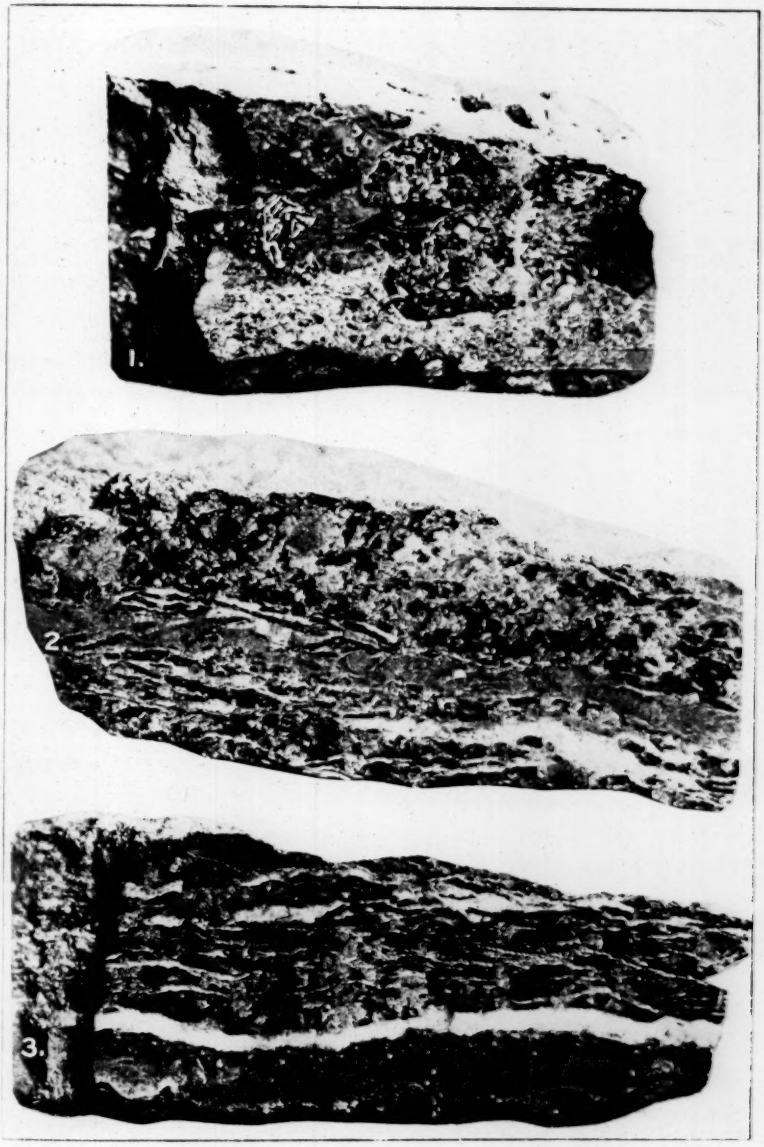
If the post-Llandovery date of the diabase is accepted, then these intrusions are brought into line with those of the Shelve area, where Professor Watts [3] has shown that the dolerites "come into contact with and somewhat alter the *Pentamerus* limestones".

Professor Fearnsides [4] concludes that the andesitic dolerites of Arenig "are of the same general age".

Dr. Harker,[5] under the impression that the cleavage and plication of the strata of Eastern Carnarvonshire were developed in pre-Silurian times, assigned a Bala age to the diabases of that area, but Professor Fearnsides [6] points out that "with increase of knowledge the supposed gap in the continuity of sedimentation has been filled up, and now a Post-Silurian date for the cleavage is generally accepted".

It appears, then, that this post-Llandovery intrusion of diabase or

[1] This power of selection is implied by Professor Watts in his description of the intrusions of the Shelve area (Proc. Geol. Assoc., vol. xiii. p. 342, 1894).
[2] Loc. cit., p. 577.
[3] Loc. cit., pp. 339–40.
[4] Q.J.G.S., vol. lxi, p. 631, 1905.
[5] *Bala Volcanic Series*, 1889, p. 76.
[6] *Geology in the Field*, 1910, p. 803.



DIABASE INTRUDED INTO LLANDOVERY LIMESTONE, RIVER EDW, RADNORSHIRE. × $1\frac{1}{2}$.

dolerite is a fact of some considerable importance in the geology of Wales and Shropshire.

The Glan-oer Type.

At Glan-oer is exposed a fine-grained igneous rock, dominantly pale grey, but with small black specks and larger whitish spots. The same type is exposed in the quarry between Little Nant and Graig-fawr, also in a dyke running N.W.–S.E. from the ford in the Nant Brook below Hendy Bank to a point south-west of Llanwefr Pool. The specific gravity is 2·69.

In thin section the rock is seen to be made up largely of a felted mass of felspar laths with somewhat ragged outlines. They are very constant in length, averaging about 0·7 mm. Alteration has gone on to a considerable extent, but they can be seen to polarize in first order colours and to exhibit lamellar twinning. Symmetrical extinction angles are always low, the maximum value observed being 12°; the felspar must approximate to oligoclase in composition. Another conspicuous constituent is a pale-green alteration product which is sometimes moulded on the felspars; the relief is not great, but the refractive index is distinctly higher than that of Canada balsam; polarization is first order grey and is of the aggregate character. There is an occasional suggestion of olivine in the shape of the pseudomorphs, and one particular case (1·2 mm. in length) places the matter beyond doubt; the substance is serpentine, and is the result of the alteration of olivine, almost certainly a variety poor in iron. It is possible that some of the felspar crystallized before the olivine, though the moulding of the serpentine on the felspar may be due to the expansion consequent on the alteration. In this connexion, though, it must be borne in mind that Professor Watts,[1] in dealing with the olivine-dolerite dykes of Antrim, has described a case where the felspar crystallized before the olivine. Some varieties of the allivalite of Dr. Harker[2] also exhibit a similar sequence of crystallization. In that rock, however, the felspar is anorthite.

Another interesting constituent is a pale-brown augite. This mineral is totally absent from some of the sections, and even in the case of those in which it occurs the distribution is somewhat eccentric. It is found in spots only large enough to enclose, perhaps, a score of felspar laths. When altered, it produces a cloudy aggregate containing much calcite; this is responsible for the whitish spots visible to the naked eye. Other constituents are apatite, fairly plentiful secondary sphene, and pyrite.

The remaining mineral is clear and fresh, with a refractive index approximating to that of Canada balsam; it polarizes in first order grey with occasional yellow. Careful search resulted in the discovery of a definite cleavage, lamellar twinning, and the fact that the refractive index is distinctly below that of Canada balsam. The mineral is biaxial and the birefringence is positive. It is undoubtedly albite. Twin lamellæ run interruptedly from one felspar to the other, though the angle of extinction changes. It is not possible at

[1] *Guide to Rocks and Fossils* (Geol. Surv. Ireland, 1895, p. 78).

[2] *Petrology for Students*, 4th ed., 1908, p. 103.

present to say definitely whether the albite is magmatic in origin or is the result of weathering.

This rock presents some points of resemblance to the Skomerite and Marloesite of Dr. Thomas,[1] but the evidence available suggests that it is newer than the Lower Arenig, to which the Skomer Volcanic Series is assigned.

ANALYSES BY J. H. WILLIAMS.

1. Olivine Basalt.

SiO_2	48·66
TiO_2	2·23
Al_2O_3	15·76
Fe_2O_3	2·66
FeO	8·16
MnO	0·14
(Ni Co) O	0·03
BaO	none
SrO	0·16
CaO	10·90
MgO	5·68
K_2O	0·05
Na_2O	1·25
Li_2O	none
H_2O at 105° C.	0·70
H_2O above 105° C.	3·04
P_2O_5	0·22
SO_3	0·43
CO_2	0·20
F	traces ?
Cl	traces
Total	100·27

2. Diabase.

SiO_2	45·82
TiO_2	1·99
Al_2O_3	16·49
Fe_2O_3	1·80
FeO	7·48
MnO	0·15
(Ni Co) O	none
BaO	none
SrO	traces
CaO	8·79
MgO	8·95
K_2O	0·35
Na_2O	2·82
Li_2O	none
H_2O below 100° C.	0·50
H_2O above 100° C.	4·89
P_2O_5	0·18
SO_3	traces
CO_2	0·04
F	traces
Cl	traces
Total	100·25

[1] Q.J.G.S., vol. lxvii, pp. 196–201, 1911.

3. The Glan-oer Type.

SiO_2	50·76
TiO_2	2·10
Al_2O_3	16·01
Fe_2O_3	0·86
Fe O	6·90
Mn O	0·11
(Ni Co) O	none
Ba O	none
Sr O	traces
Ca O	3·55
Mg O	8·02
K_2O	0·81
Na_2O	3·78
Li_2O	traces?
H_2O below 100° C.	0·41
H_2O above 100° C.	5·33
P_2O_5	0·26
FeS_2	0·41
CO_2	0·61
F	none
Cl	traces
Total	99·92

In conclusion, I wish to express my indebtedness to Miss Chamberlain, who placed her notes and maps at my disposal, to Dr. Morley Davies, who identified the fossils, and to Professor Watts, who looked through the proofs and made valuable suggestions.

EXPLANATION OF PLATES XVIII AND XIX.

Plate XVIII.

Fig. 1.—Augite moulded on felspar, N. of Llanwefr Pool. (Diabase.) × 16.
,, 2.—Ilmenite moulded on felspar and augite, Graig-fawr. (Diabase.) × 35.
,, 3.—Olivine basalt, E. of Little Wern. × 27.
,, 4.—Pseudomorph after olivine, S.W. of Llanwefr Pool. (Glan-oer type.) × 31.
,, 5.—Ophitic structure, Glan-oer. (Glan-oer type.) × 34.

Plate XIX.

Figs. 1–3.—Specimens of diabase intruded into Llandovery Limestone from River Edw, S. of Pye Corner, Radnorshire. × 1½ nat. size.

V.—Notes on Yunnan Cystidea. 1. *Sinocystis* and *Ovocystis*.

By F. A. Bather, D.Sc., F.R.S.

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Before returning to Calcutta the specimens described in his memoir "Ordovician and Silurian Fossils from Yun-nan" (1917, Palæont. Ind., n.s., vol. VI, Mem. 3), Dr. F. R. Cowper Reed very kindly lent to the Geological Department of the British Museum the figured cystids, in order that plaster casts of them might be made and kept there for reference. This was done, and a set of the casts was also furnished by the Department to the Sedgwick Museum, Cambridge. While preparing the specimens for the moulder, I had the opportunity of studying them with some

care. Although Dr. Reed has published good figures, drawn with Mr. T. A. Brock's usual exactitude, and descriptions, on the fulness of which he will perhaps allow me to compliment him, nevertheless the notes made by me, when still unacquainted with his valuable work or with the views therein expressed, do contain supplementary matter, which it seems better to publish now rather than to reserve for some revision in an uncertain future.

ORIENTATION.

To avoid confusion, it is necessary to explain that the terminology and orientation here employed are the same as those used by me in describing the cystids from the Northern Shan States (1906, Palæont. Ind., N.S., vol. II, Mem. 3), also in Lankester's "Treatise on Zoology" (1900), and elsewhere. As regards the terminology of the various parts and organs, Dr. Reed and I are in general agreement; but the orientation adopted by Dr. Reed is unfamiliar. To

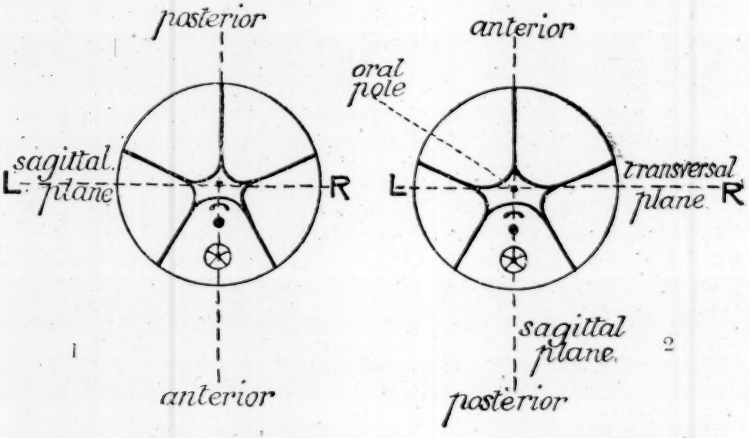

FIG. 1.—A diagram of the adoral face of a simple five-rayed Pelmatozoön, showing peristome, hydropore, gonopore, and periproct; the orientation indicated according to F. R. Cowper Reed.

FIG. 2.—The same; the orientation indicated according to F. A. Bather.

meet the difficulty that I found in interpreting it, Dr. Reed has kindly marked his main lines on the accompanying diagrams (figs. 1 and 3), beside which my own scheme (figs. 2 and 4) is placed for comparison. In both cases the 'vertical axis' runs from the oral centre (my 'oral pole') to the centre of the base (my 'apical pole'), and all the diagrams are viewed from above the oral pole.

From his diagrams and letters it appears that the basis of Dr. Reed's scheme is the 'sagittal plane', which he takes as passing through the vertical axis in the direction of the mouth-extension, or, in a normal five-rayed form, between the pair of rays enclosing the hydropore ['bivium'] and the remaining three rays ['trivium']. The 'antero-posterior plane' of Dr. Reed cuts the sagittal plane at right angles on the vertical axis; the anterior face of the theca is that on which the hydropore lies, and (usually) the anus.

It is not necessary to enquire whether this scheme is used quite consistently by Dr. Reed; it is doubtful whether it could be. Nor need one do more than point out that Dr. Reed strays no less from general custom in his use of the terms 'pole', 'meridian', 'right' and 'left'.

Unfortunately Dr. Reed believes himself to have been following the chapters in the "Treatise on Zoology" as his 'authority', a compliment which is so effective a criticism of their lucidity that it is necessary to make their scheme plainer in so far as it applies to Cystidea.

A **pole** is a point at which an imaginary axis cuts the circumference of the theca.

The **oral pole** coincides with the centre of the peristome (*vide infra*).

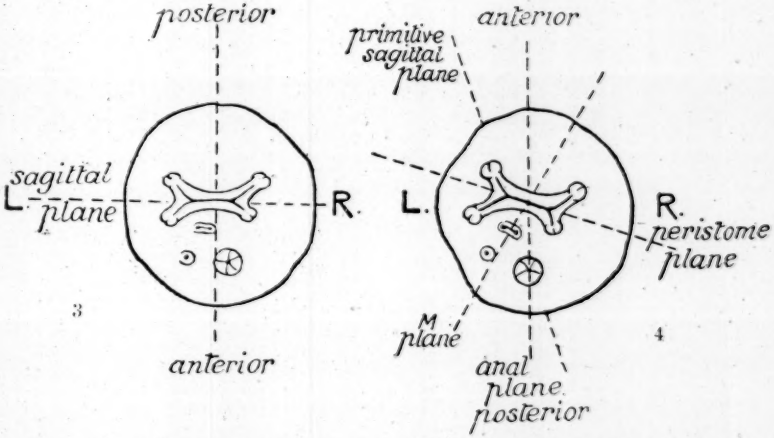

FIG. 3.—A diagram of the adoral face of *Sinocystis mansuyi*, after Reed, 1917, pl. II, fig. 7; the orientation according to Reed. × ⅔.

FIG. 4.—The same; the orientation according to Bather. The evidence for the "primitive sagittal plane" is given in the notes on *S. loczyi* (part II, fig. 8).

The **apical pole** coincides with the centre of the basal attachment, or with the centre of the system of plates in that region.

A specialized **apical system** of plates comparable with that of Crinoidea and Echinoidea has rarely been attained in Cystidea.

The **vertical axis** cuts the theca at the oral and apical poles.

The region of the thecal surface surrounding the oral pole is the **adoral face.**

The region surrounding the apical pole is the **adapical face.**

The thecal openings are normally four: the **peristome,** often called the 'mouth', but that organ, strictly speaking, lay within it and may have occupied but a small part of the peristomial area; the **periproct,** often called the 'anus', but that organ lay within it and occupied only a part of the periproctal area; the **hydropore,** sometimes in the form of a 'madreporite', usually lying close to the

peristome; the **gonopore** is the name frequently applied to the 'fourth opening' on the assumption that through it the gonads were emitted, but Jaekel calls it the 'parietal pore' on the assumption that it was the opening of a persistent parietal canal—the two assumptions are by no means mutually exclusive. Primitively these four openings lie in a straight line which probably indicates the attachment of the dorsal vertical mesentery to the inner wall of the theca; their order is peristome, hydropore, gonopore, periproct.

In this series the peristome (mouth) is **anterior**; the periproct (anus) is **posterior**. The line joining these two is the **oro-anal axis**.

The theca being placed with its oral pole uppermost and with the anus towards the observer, then the **right** and **left** of the theca correspond with the right and left of the observer. In representations of all Echinoderma, figures representing the adoral or adapical faces should be placed on the paper so that the right side of the creature is towards the right side of the page. Side-views of Pelmatozoa should have the adoral end uppermost.

The **antero-posterior plane** or **anal plane** passes through the oro-anal axis and the vertical axis. A line drawn in this plane and bisecting the vertical axis at right angles would be the **antero-posterior axis**. This does not coincide with the oro-anal axis, and the concept is rarely required.

As regards the **sagittal plane** there is perhaps room for hesitation. When the thecal openings all lie in the antero-posterior plane, then that plane is the sagittal plane, as it would be in any symmetrical animal. The plane at right angles to it and passing through the vertical axis is then the **transversal plane** (Text-fig. 2).

In many cystid genera asymmetry is manifested in a migration of the anus and in a correlated or an independent shifting of the gonopore. The oral pole being regarded as fixed, then it appears that the hydropore (or madreporite) undergoes less lateral change of position than the other organs. The plane through the vertical axis and the hydropore may therefore not coincide with the antero-posterior plane; it needs a distinct name, and I have called it the **M plane** (= madreporite plane) (Text-fig. 4).

It seems best to limit the term 'sagittal' to its primitive morphological use, available only for outwardly symmetrical or almost symmetrical forms; and for asymmetrical forms to use the terms 'anal plane' and 'M plane'. When a sagittal plane cannot be fixed, then it is inaccurate to use the term 'transversal', and another term (should one be thought necessary) must be found for the plane passing through the vertical axis and the peristomial extension, which plane in pentamerous Pelmatozoa separates the bivium (radii C D) from the trivium (radii E A B); it may be called the **peristome plane**. As a rule, but not always, the plane which Dr. Reed has termed 'sagittal' corresponds roughly to this peristome plane. In Pelmatozoa the peristome plane usually lies approximately at right angles to the M plane, but this arrangement is not inevitable. In the Spatangoid sea-urchins the peristome plane separates the bivium (A B) from the trivium (C D E)—quite a different plan; theoretically it forms an angle of 54° with the

M plane, and the plane (radius D; interradius A B) to which it is at right angles is the plane of test-elongation known as 'Loven's plane' (see "Treatise", 1900, pp. 19–22, fig. xviii). Such facts as these show that the peristome plane has been fashioned in different groups in response to different adaptations, and that in each group it is of later origin than the M plane and the anal plane, just as they are, *ex hypothesi*, later than the sagittal plane.

Sinocystis and Ovocystis.

About ninety specimens from the Ordovician limestones and calcareous mudstones of Shih-tien (Reed's rock-types *g* and *h*, Coggin Brown's beds 5 and 5*a*) are relatively large cystids belonging to the family Sphæronidæ of the Diploporita. Twenty-one of these, being figured specimens, were studied by me and will here be referred to by the numbers of the plate-figures, since they were unprovided with any other reference-number. They are distributed by Dr. Reed between his two new genera *Sinocystis* (*S. loczyi*, I, 1–8, and *S. yunnanensis*, I, 9, 10, II, 1, 16: n.spp.) and *Ovocystis* (*O. mansuyi*, n.sp., II, 2–11). They agree, however, in a number of characters, which may be summarized as follows:—

Theca variable in shape but roughly ovate pyriform, tapering to the base of attachment which may be prolonged as a short unspecialized stalk; composed of numerous (100–600) irregular, polygonal, stout plates, bearing conspicuous diplopores. Oral pole approximately in the centre of the rounded summit of the theca. Peristome extended approximately at right angles to the anal plane (probably an elongate rectangular opening) with two short food-grooves diverging at each end (one at each corner) and each ending on a brachiole-facet (possibly more than one); mouth and epithecal food-grooves with irregular cover-plates interlocking across the middle line and apparently fixed. Periproct on the adoral face, about half-way between oral pole and periphery, hexagonal or pentagonal, with 6 or 5 covering valves. Hydropore slit-like, lying slightly to left of anal plane, close to peristome. Gonopore pentagonal to circular, on left of periproct.

The three species are well founded: they may be distinguished by their diplopores, if by nothing else. *S. yunnanensis* is, no doubt, of the same genus as *Sinocystis loczyi*; but why is *Ovocystis mansuyi* separated? Examination of the generic diagnoses provided by Dr. Reed reveals the following alleged differences.

The periproct of *Sinocystis* is hexagonal, of *Ovocystis* pentagonal. This is really a point of no importance; but in any case the rule is open to exception, for in *O. mansuyi* the outline seems to be hexagonal in specimen II, 6.

The diplopores of *Sinocystis* are, it is said, covered by tubercles of epistereom; those of *Ovocystis* are not covered by epistereom. This is a very doubtful point. In all three species there is a tendency for the stereom immediately surrounding each pore-pair to be raised, so as ultimately to form a sort of tubercle. In *S. loczyi* the pores open on a rounded elevation surrounded in some cases by a faint moat. This elevation may reach a height of 1·7 mm. above the test

(specimen I, 8), and as it grows upwards there is certainly a tendency for the epistereom to block the pores, but I was unable to convince myself that it ever actually succeeded (Text-fig. 5). In *S. yunnanensis*, where the pore-pairs are more numerous than in *S. loczyi*, they have, for the sake of space, to assume a more regular arrangement, and so the long axis of each elevation is on a line radiating from the umbo of the plate; but they are not in continuous lines. At the umbo of each plate the growth of the elevations is such that the whole epistereom of the umbo is often raised into a kind of turret surrounding a few diplopores. These turrets were only found preserved on those regions of the theca from which the matrix had not been weathered away; probably they had been worn down in the other regions. On other parts of the plate there are sometimes elevations similar but subsidiary to that at the umbo (e.g. I, 1); in some cases a plate with about five of these in a circlet round the umbonal turret resembles a cidarid plate with its primary and secondary tubercles. Excessive growth of epistereom, especially in the turrets, may perhaps close the pores occasionally; but I could not be any more sure that it did so in this species than in *S. loczyi*.

5 6 7

FIG. 5.—*Sinocystis loczyi*: a group of tubercles bearing open diplopores, seen from the side, on a fragment extracted from soft matrix accompanying specimen I, 8. × $\frac{8}{1}$.

FIG. 6.—*Sinocystis mansuyi*: an elevation bearing a diplopore, seen from above and from the side, on specimen II, 5. × $\frac{8}{1}$.

FIG. 7.—A root attached to the theca of *Sinocystis mansuyi*, II, 6, a little above its base. × $\frac{2}{1}$.

In *O. mansuyi* the fairly numerous but irregularly distributed diplopores appear in some cases (e.g. II, 2) to be sunk directly through the test, without either elevation or peripodium. This appearance may, however, be due to wearing down; for in II, 8, each pore-pair is surrounded by a slight elevation dying away into the test, and in well-preserved tracts of II, 5 the elevation is still more definite and rises higher between the pores of each pair so that the openings lie on its shoulders (Text-fig. 6). In unworn tracts of II, 9, 10, and 11, the elevation is relatively high and well-defined, and occasionally suggests a tendency to be so directed that both openings face upwards, i.e. in an adoral direction (especially in II, 9). In this species the epistereom does not grow up round the pores so strongly as in *S. yunnanensis* or even *S. loczyi*, and there is never any appearance of blocking.

Although I was unable to prove the closing of any diplopores in these fossils, Dr. Reed presumably has satisfied himself that it does occur in both his species of *Sinocystis*. If so, it should probably be regarded as a character of old age, and not as diagnostic of a genus. It is difficult to believe that the closing of true diplopores by

epistereom can ever have been a normal character of the adult in any species: the structures seem so clearly adapted for the passage of some aërating organs (papulæ) through the test; and the very fact that the epistereom does grow up in tubercles and turrets indicates the constant outward extension of those organs. In opposition to this view, the only previous evidence of weight has been Professor O. Jaekel's account of a thin reticular layer covering diplopores in a fragment of "*Calix sedgewicki*" from Bussaco (1899, Stammesgesch. d. Pelmatozoen., p. 72), an observation as yet isolated and unconfirmed (see, however, discussion of *Trematocystis* in Part III).

The last point of difference mentioned in Dr. Reed's diagnoses is thus expressed: *Sinocystis*, "No food-grooves on surface"; *Ovocystis*, "Surface of theca provided with irregular shallow food-grooves meandering between plates, with local traces of stronger meridional and concentric or spiral grooves." It is, as previously stated, the case that *Sinocystis*, no less than *Ovocystis*, has short epithecal food-grooves leading from the corners of the peristome to the brachiole-facets. But certainly it has no others, and that is what Dr. Reed means. If *Ovocystis* has these meandering food-grooves in addition, it differs in this respect not merely from *Sinocystis* but from every pelmatozoön yet described, and is a remarkable form indeed.

Unfortunately I was not acquainted with Dr. Reed's observations till some time after the specimens had been returned to Calcutta. I had, however, carefully examined, under a binocular dissecting microscope, the whole surface of the ten specimens lent to the Museum, and it is difficult to believe that such unusual structures could have escaped notice. I have subsequently examined the plaster-casts carefully made by Mr. F. O. Barlow, and can see between the plates nothing that suggests a food-groove. Dr. Reed in his description (p. 8) certainly adds that the grooves are "obscure", but he also gives a fairly definite account of their course. He distinguishes three kinds: (1) "shallow . . . grooves irregularly meandering along the suture-lines . . . and frequently uniting"; (2) "one or more stronger sinuous longitudinal trunks running meridionally down anterior face" [= posterior side]; (3) "one or more concentric or obscurely spiral sinuous trunks on the posterior [= anterior] face in the lower third." He figures no details of these grooves, and not one of Mr. Brock's enlarged drawings of the surface shows the smallest trace of them. Only fig. 5 on pl. II, which represents a theca with weathered and imperfectly preserved surface, is said to show "traces of spiral grooves" on the "posterior side". Actually the view is of the right side, the theca being compressed in the anal plane, and the hydropore lying under a prominence shown at the top of the figure about 1 cm. to left of the median line. The post-mortem compression of the theca has pushed the greater part of this right side in, so that there is a sharp bend or crack down the anterior edge (right hand of figure); and on the upper posterior edge (left of figure) the plates are pushed slightly under those of the other and less compressed half of the theca. The depression thus produced is continued as an

irregular curved groove across the right side of the theca in its lower third, and this is clearly (perhaps too clearly) shown passing across the drawing. The groove was interpreted, with the specimen before me, as evidence of slight folding accentuated by weathering; some fainter folds, also the result of post-mortem compression, are obscurely indicated below this main groove, and are brought out in the drawing. If this is all that Dr. Reed has to offer in support of his 'food-grooves', he must not be surprised if their existence is denied. Grooves and folds just as clear are shown in specimens of *Sinocystis* (see pl. I, figs. 6 and 7), a genus in which such 'food-grooves' are rightly said to be non-existent.

Clear and undoubted evidence is required, for *a priori* arguments are certainly opposed to Dr. Reed's interpretation. Dr. Reed compares the alleged food-grooves to those of *Fungocystis*, *Pyrocystis pirum* (*apud* Jaekel), and *Gomphocystis*. In the two former the food-grooves, as usual in Glyptosphæridæ, cut across the thecal plates and do not follow their sutures. In *Gomphocystis* certain thecal plates have assumed a more definite arrangement as floor-plates of the grooves, which follow a spiral but quite definite course wholly unlike that described for *Ovocystis* by Dr. Reed. In all three genera, as indeed in all Diploporita, the epithecal food-grooves end on exothecal brachioles, of which the facets at any rate are visible. The cover-plates of the grooves are not preserved in all specimens of Diploporita, though the notches for their reception may often be detected; but in forms with such solid and well-preserved cover-plates as *Sinocystis* and *Ovocystis*, some traces of them would certainly be found on any extensions of the subvective system that might occur. No traces of cover-plates are visible on the alleged extensions in *Ovocystis*. Finally in all Pelmatozoa the food-grooves lead to the peristome; and this arrangement is conspicuous in all Diploporita. In *Ovocystis mansuyi*, as in both species of *Sinocystis*, there is a particularly evident subvective system, with brachiole-facets and strong cover-plates. There is not the smallest trace of any extension from this compact system over the general surface of the theca, nor has Dr. Reed ventured to describe or portray any connection between this system and his vaguely meandering, or longitudinal meridional, or concentric spiral grooves.

The simple fact is that the thecal plates of *Ovocystis mansuyi* are, as Dr. Reed puts it, "thick swollen"; in other words, the suture-lines are depressed. But there is no evidence that extensions of the subvective or any other system passed along these depressions.

Many specimens of *O. mansuyi* (e.g. II, 3, 4, 6, 8, 10) are distinguished from all [?] the specimens of *Sinocystis* by bearing on some of their thecal plates structures which Dr. Reed calls "small circular isolated raised cup-like pseudo-brachiole facets"; and, when the specimens were in my hands, being unable to discern any other points of difference, I supposed in my ignorance that Dr. Reed had based his genus to some extent on these appearances. Therefore, though not in much doubt as to their true nature, I was led to examine them with some care. This is fortunate, since Dr. Reed seems undecided "whether to interpret these structures as features

of classificatory importance or as individual peculiarities due to accident or as resulting from some extraneous cause". He is right in regarding the last interpretation as the "most probable"; the structures are in fact the root attachments of some other Pelmatozoön, and similar appearances are familiar enough to those who have studied Ordovician cystids in the field. In II, 3, there is a small one near the base, and this, as drawn in fig. 3, has a circular lumen. In II, 4, there is near the base a rather large one, 4 mm. high, 4·7 mm. wide at its summit, and 6·7 mm. wide where it rests on the theca; it is divided by a stellate lumen into irregular pentameres. By removing the thecal plate on which this rests and examining its inner surface it is seen that the encrusting root covers several diplopores. That the covering up of the diplopores took place gradually as the root extended appears from a few incipient roots on the better preserved face of the same specimen, for in them the pores still pierce the outer extensions of the incrustation. This face of the theca bears five such roots, and two of them, which also are quite small, have a sub-pentagonal cup-like excavation, reminiscent of the Liassic *Cotyleerinus*. Near the lower end of II, 6, there is a relatively large root-base which rises sharply from the test like a broken volcanic cone (Text-fig. 7); its diameter below is 8 mm., and above about 4·5 mm. In II, 8, a somewhat similar root covers the anal pyramid. On the anterior face of II, 10, which is the less flattened face and presumably lay upwards, there are three, perhaps four, root-bases, more or less merged in the test. The object which in II, 5, covers the hydropore (*v. supra*, p. 513, line 7 from end) may or may not be such a root.

The preceding facts prove that the roots were independent of the cystid on which they grew, that in some cases they must have established themselves on the theca after the death of the cystid, but that in other cases they settled on it and continued to grow, at least for a time, during the life of the cystid. When in the last-mentioned case the cystid deposited its own stereom round and partly over the stereom of its unbidden guest, then a difficulty was created for the modern palæontologist.

All the points of supposed difference between *Ovocystis* and *Sinocystis* have now been discussed and shown to be non-existent or unimportant. It follows that *Ovocystis* is a synonym of *Sinocystis*, which now contains the three species *S. loczyi*, *S. yunnanensis*, and *S. mansuyi*. The nomen nudum *Sinocystis piroides* Reed (in Coggin Brown, 1913, Rec. Geol. Surv. India, xliii, p. 332) is said in the 1917 memoir (p. 60) to be a synonym of *Pyrocystis* (?) *orientalis* Reed; it was provisionally attached to the larger of the two specimens from locality K 15/302.

Since Dr. Reed has not named a Genotype for *Sinocystis*, the species *S. loczyi* is hereby selected.

Before the systematic position of *Sinocystis* is discussed, further notes on the specimens will be given.

REVIEWS.

I.—Some Recent Work on Mesozoic Floras.

1. On the Cretaceous Flora of Russian Sakhalin. By A. Kryshtofovich. Journ. of the Coll. of Sci. Imp. Univ. of Tokyo, vol. xl, art. 8, pp. 73, with 15 text-figures, 1918.
2. Mesozoic Floras of Queensland. By A. B. Walkom. Part I continued: The Flora of the Ipswich and Walloon Series, (*c*) Filicales, etc. Queensland Geol. Surv. Publ., No. 257, 1917, pp. 66, with 10 plates and 12 text-figures. Part I concluded: (*d*) Ginkgoales, (*e*) Cycadophyta, (*f*) Coniferales. Queensland Geol. Survey Publ., No. 259, 1917, pp. 48, with 9 plates.
3. The Earlier Mesozoic Floras of New Zealand. By E. A. Newell Arber. New Zealand Geol. Survey Palæontological Bull., No. 6, 1917, pp. 80, with 14 plates and 12 text-figures.

1. The Island of Sakhalin possesses a fossil flora, rich in species, which has hitherto been regarded as exclusively of Miocene age. Kryshtofovich—who recently visited the western coast of the island, examining nearly 200 outcrops with plant remains—claims, however, to have established that this so-called Miocene flora belongs to several geological horizons, not only of the Tertiary period but also of the Cretaceous. He points out that so-called "Arcto-Tertiary" floras in other parts of the world might also repay thorough revision.

The part of the Cretaceous of Sakhalin known before, and represented by marine deposits, has been hitherto considered as belonging to the Senonian, and its thickness estimated at 3,500 feet. But the present author's work has indicated the presence of Turonian, Cenomanian, and probably even older divisions of the Cretaceous, thus making the total thickness at least 7,000 feet. He proposes a classification of these Cretaceous rocks, based on the plant remains.

2. The two memoirs by Walkom with which we are here concerned form the conclusion of his study of the flora of the Ipswich and Walloon Series, of which the first instalment appeared in 1915 as Publication 252 of the Queensland Geological Survey. It is pointed out that the results so far obtained indicate that the flora of the Walloon Series is Jurassic, probably corresponding to the Liassic or Lower Oolite of Europe, while the Ipswich Series is Triassic, or possibly equivalent to the so-called Rhætic beds of various areas.

3. The plant impressions discussed in Arber's memoir upon the Mesozoic Floras of New Zealand are derived from rocks whose age ranges from Triasso-Rhætic to Neocomian. In the provinces of Canterbury and Otago Rhætic floras occur. Jurassic floras are met with in the provinces of Canterbury, and especially Southland, while a Neocomian flora occurs in Auckland, but no evidence of an undoubted Upper Jurassic flora has yet been met with. Prior to the commencement of the work of which the results are recorded in the present paper, there were only eleven valid records of Mesophytic plants from New Zealand, but the author has been able to add

thirty-seven species to those already known. Of these at least fourteen species are new.

Arber concludes from his examination of the fossil floras that there is no evidence, at the time of writing, of any terrestrial vegetation in New Zealand older than the Triasso-Rhætic, and he considers that, on the known evidence, New Zealand did not form any part of the Permo-Carboniferous continent of Gondwanaland, although in Rhætic, and probably also in Jurassic times, New Zealand and Tasmania were united with Australia as one large connected land area. Professor Seward is inclined to recognize a close alliance between the Mesozoic genus *Linguifolium*, which occurs in New Zealand, and the genus *Glossopteris*, which characterized the Gondwanaland flora, but Arber, in the present paper, gives detailed reasons for maintaining the distinctness of these two genera.

The flora of Waikatô Heads, Auckland, is of particular interest as being perhaps one of the oldest, in a geological sense, of the known Neophytic floras. Professor Laurent, of Marseille, contributes a description of two Angiosperms obtained from these beds, one of which is fragmentary, while the other consists of leaves which he refers to a new species of the genus *Artocarpidium*.

A. A.

II.—Memoir of John Michell. By Sir Archibald Geikie, O.M., K.C.B., F.R.S. pp. 107. Cambridge University Press, 1918.

GEOLOGISTS owe a considerable debt to Sir Archibald Geikie for his contributions to the history of their science. That debt is further increased by the issue of this memoir, dealing, as it does, with the life and work of a man who, though little known at the present day, held a position of no small note among his contemporaries.

John Michell, to use an often-repeated phrase, was a man of parts; he was one of those persons of wide interests and accomplishments who adorned the front rank of scientific men in the eighteenth and early nineteenth centuries, but who have, unhappily, been swept away by the advance of modern progress and its accompanying necessity for specialization. He was, of course, a classic and mathematician, and in addition to his geological work he carried out experiments in physics and devoted a considerable amount of time to astronomical observations, which he performed with a reflecting telescope made by his own hands.

He was elected to a Fellowship of Queen's College, Cambridge, at the age of 25, in the year 1749, and held a number of offices in the University till 1762, when he was elected to the Woodwardian Professorship of Geology. This office he only held for about two years, when he was obliged to resign from it on the occasion of his marriage. From this time onwards he held in succession the benefices of Compton, Havant, and Thornhill, at the last of which he died in the year 1793.

Being a man of a somewhat modest and retiring disposition he has

left little published work; his most important geological communication was his paper on earthquakes, which was read at five successive meetings of the Royal Society in 1760, and which met with such approval that he was shortly afterwards elected a Fellow. In addition to this work he spent much of his leisure time in geological excursions, and in these obtained a wonderfully accurate idea of the correlation of the strata of the south and east of England, based entirely on lithological characters, which, fortunately, was put in writing by one of his friends and has thus been preserved. He was a friend of many of the chief men of science of his day and more especially of Herschell and Cavendish, with both of whom he frequently corresponded on scientific matters. It is on record that the first idea of using the torsion balance as a means of determining the density of the earth was suggested to Cavendish by Michell, who, indeed, made such an apparatus, but not, however, one of sufficient delicacy for the purpose, so that it was left for Cavendish to carry the experiments to a successful conclusion. His only other published work was a small book on artificial magnets, which embodied much of the experimental work he did while at Cambridge.

This memoir, written in the author's accustomed literary style, is eminently readable, and contains a very interesting account of this little-known Woodwardian Professor.

W. H. W.

III.—Recent Discoveries relating to Early Man in America. By Aleš Hrdlička. Smithsonian Institution, Bureau of American Ethnology, Bull. 66, 1918, pp. 65, pls. xiv.

ACCORDING to Dr. Hrdlička there is still no evidence of really fossil man in North America. He refers especially to the human remains found in the asphalt of Rancho La Brea, California (J. C. Merriam, *Science*, N.S., vol. xl, pp. 198–203, 1914), and to those found with Pleistocene mammals at Vero, Florida (see Geol. Mag., Dec. VI, Vol. IV, p. 4, 1917). The skeletons at Vero are said to be undoubted interments, and the remains from La Brea also appear to be those of a modern American Indian.

IV.—American Fossil Horses.

Equidæ of the Oligocene, Miocene, and Pliocene of North America, Iconographic Type Revision. By Henry Fairfield Osborn. Mem. American Mus. Nat. Hist., N.S., vol. ii, pp. 1–217, pls. i–liv, and 173 text-figures, 1918.

THE evolution of the horses in North America has long excited wide interest, and has been much discussed in popular writings as well as in scientific memoirs. The statements of fact needed for this discussion, however, have hitherto been scattered in numerous technical notes and papers, often without adequate illustration, and it has been difficult to realize the nature of the evidence. We are now indebted to the American Museum of Natural History for an exhaustive summary of the known Oligocene, Miocene, and Pliocene species, with exact copies of all the original published figures of the

fossils and with drawings of all the described specimens which have not hitherto been figured. It is a most valuable work of reference and indispensable for further progress. It is now possible to understand how fragmentary is our knowledge of the various genera and species, and how much scope there is for differences of opinion on all points except generalities. The broad outlines of equine evolution are clearer than ever, and Professor Osborn has had prepared new series of beautiful drawings to illustrate the changes in the upper and lower molar teeth and in the feet. The excellent manner in which the stratigraphical position of the various fossils is determined is also fundamentally important. We are only inclined to ask for more, and would add to our congratulations our best wishes for the speedy accomplishment of Professor Osborn's promised Monograph of the Equidæ.

V.—The Cretaceous Theropodous Dinosaur *Gorgosaurus*. By Lawrence L. Lambe. Canada Dept. of Mines, Memoir 100, Geological Series, Ottawa, 1917.

In this excellently illustrated memoir the author gives a full account of a nearly complete skeleton of a large carnivorous Dinosaur, *Gorgosaurus libratus*, found in the Belly River (Cretaceous) beds of Alberta, Canada. This reptile is, in most respects, very similar to *Tyrannosaurus*, but is said to differ from it in several important particulars, e.g. in the structure of some of the teeth, the proportions of the limbs, and the great development of the plastron of ventral ribs. The fore-limb is curiously small, less than one-fourth the length of the hind-limb. It possesses only two complete digits (1 and 2), with powerful claws, and a vestige of the third metacarpal; the radius and ulna are very short. The hind-limb is remarkable for the great elongation of the foot, which, though much larger, is very similar to that of *Ornithomimus*. It possesses three complete digits (2, 3, 4) and the distal portion of the first, all claw-bearing. The fifth is represented by a vestige of the metatarsal only. The ventral buckler is very well developed, and consists of about nineteen transverse rows of ventral ribs, two pairs in each row. In the first and last the median pieces are fused, but in the others they remain distinct but overlap, and are firmly attached to one another, there being no median more or less V-shaped element such as usually occurs in reptiles with such a plastron. The author discusses the probable appearance and habits of this reptile, giving several restorations of it in what he believes to be characteristic attitudes. He considers that, although its mode of progression was bipedal, in a semi-erect position, and well raised from the ground, that when at rest the animal squatted, supported on the expanded ends of the pubes, or lay extended on its ventral surface. The absence of wear on the teeth suggests that the food was soft and obtainable without much effort, probably consisting mainly of the flesh of carcases of other reptiles such as the large Trachodont Dinosaurs.

C. W. A.

VI.—Fossil Insects in Coal-measures.

Two Insects from Commentry.—R. J. Tillyard (Proc. Linn. Soc. N.S. Wales, xliii, pp. 123–134, March, 1918) discusses two fossils recently described by H. Bolton (Manchester Memoirs, May, 1917). He suggests that *Megagnatha odonatiformis* Bolton, is an ancient representative of the Order Embioptera, and erects for it a new family, Megagnathidæ, differing in greater size and more complex venation, as well as, probably, in the shorter comparative distance between the bases of the fore- and hind-wings. *Sycopteron symmetricum* Bolton, "is very likely an archaic type of the Order Psocoptera, related to *Amphientomum* of the Oligocene, but considerably less specialised" in its venation.

VII.—Rock-boring Organisms as Agents in Coast Erosion. By Professor T. J. Jehu. Scottish Geographical Magazine, vol. xxxiv, pp. 11, with 3 figures, January, 1918.

In this paper the author lays stress on the importance of the part played by rock-boring organisms in submarine erosion, and more particularly in the lowering of the foreshore, with the consequent further exposure of the cliffs to the wearing action of the waves. He shows how this process is carried on to a very great extent near Cromer and Brighton, where the chalk forms the sea bottom and foreshore, and also at St. Andrews, where the rocks are sandstone, shale, and limestone. The rocks are perforated by the organisms, with the result that they are converted into a honeycomb-like network, which is easily broken down by mechanical agencies, at first to an irregular surface, which is soon planed down to an even platform at the new lower level. This destruction is not continuous, as it can only take place where the rock is free from loose overlying sediment, but in the absence of such sediment it proceeds in very many places, and at an average rate of about 1 inch per annum.

The work is carried out by a great variety of forms, including annelids, sponges, molluscs, and echinoderms; these creatures mostly prefer soft or calcareous rocks, but some, more especially *Pholas*, bore into any kind of rock, including sandstone, mica-schist, and gneiss. The means by which this animal bores the rocks are somewhat obscure and many different suggestions have been put forward. These are summarized as follows:—

1. That the perforations are made by rotations of the shell-valves, after the manner of augers.

2. That the holes are made by rasping, effected by siliceous particles in the foot, or mantle, or both.

3. That the excavations are due to ciliary currents, aided by rasping.

4. That the boring is carried out by the foot exerting suction.

5. That the rasping is brought about by the friction of gritty particles of external derivation against the walls of the burrows.

The balance of evidence goes to show that, at any rate in the case of the Pholadidæ, the action is mechanical, though acid secretion may play some part. In experiments carried out by Miss B. Lindsay

at the Gatty Marine Laboratory at St. Andrews, it was shown that the action was one of suction accompanied by scraping.

W. H. W.

VIII.—The Dry Lakes and Lands of Western Australia.

Erosion and resulting Land Forms in sub-arid Western Australia, including the Origin and Growth of the Dry Lakes. By J. T. Jutson. Geogr. Journ., pp. 418–37, 2 pls., December, 1917.

On the Formation of "Natural Quarries" in sub-arid Western Australia. By J. T. Jutson. Proc. Roy. Soc. Victoria (N.S.), xxx, pp. 159–64, pls. xxviii, xxix, March, 1918.

The Influence of Salts in Rock Weathering in sub-arid Western Australia. Tom. cit., pp. 165–72, pl. xxx, March, 1918.

THE dry lakes of the Salt Lake Division, north of Coolgardie and Kalgoorlie, have been ascribed by some authors, e.g. C. G. Gibson and J. W. Gregory, to river-systems of Tertiary, probably Miocene, time. H. P. Woodward believed them to be wind-planed flats. Mr. Jutson, while admitting the possibility of Miocene rivers, does not believe that there can be any direct connection between them and the present lake system. Given an undulating surface, such as the present contour of the country suggests, then, in his opinion, the existing agents seem competent to produce all the existing phenomena, including valleys, plains, and lakes. The lakes appear to have been formed by the processes of advancing sands, formation of sand-bars, recession of lake-shore cliffs, and planing and hollowing out of rock floors. These processes have resulted in the formation, dismemberment, migration, growth, capture, and union of lakes. Many factors are responsible for the results obtained, amongst which the wind is regarded as playing a prominent part.

The "Natural Quarries" are circular, rectangular, and triangular excavations, resembling artificial quarries, in the hillsides of various rocks. Mr. Jutson believes that they are due to the undermining action of rain under special conditions, which he describes.

While the action of wind and the variations of temperature are important agents in producing the configuration of the sub-arid region, as they are in other deserts, something must also be assigned to the crystallization of salts contained in the rocks in solution and brought to the surface by capillary attraction, when the water then evaporates. By the expansion due to crystallization flakes or grains may be forced off or a soft rock may crumble. To such a process Mr. Jutson restricts the term "exsudation". It is chiefly observed at the base of cliffs at the edge of a dry lake. It undermines the cliffs and the debris are carried away by wind, so that the billiard-table floor is produced. It is curious that no pronounced efflorescences have been noticed in these situations, though they seem to occur on rocks that are more exposed to the sun.

F. A. B.

IX.—Imperial Institute Monographs: Zinc Ores. pp. 64. Published by the Imperial Institute, 1917. Price 2*s*.

THIS monograph is the first of a series now in preparation, under the auspices of the Mineral Resources Committee of the Imperial Institute. Its object is to give a general account of the world's production and resources of zinc ores, with special reference to the British Empire. The compilation is chiefly due to Messrs. S. J. Johnstone and T. Crook, who have carried out their work very thoroughly; all available sources of information have been effectively sifted and the results condensed into a handy form. The memoir contains sections on zinc minerals, the world's production of zinc ores, the ore deposits of the British Empire and of foreign countries, the valuation, concentration, smelting, and price of the ores, commercial spelter, and on the properties and uses of the metal. The treatment adopted is partly geological and partly statistical, together with references to the methods of mining and degree of development of the individual deposits. The descriptions of the actual manner of occurrence of the ores are often somewhat slight, but this is probably not the fault of the authors, since such information is usually very difficult to obtain from the scattered literature of mining geology. Furthermore, at the present time many new developments are taking place in this and other branches of mining as to which details are not yet available. However, the difficulties inherent in a work of this sort have been successfully surmounted, and the Committee are to be congratulated on having made an excellent beginning of a series which cannot fail to be of great permanent value to the mineral industries of the Empire.

X.—The Limestones of South Africa.

THE Geological Survey of South Africa has published a memoir on the Limestone Resources of the Union, by W. Wybergh (Pretoria, 1918), containing a very full account of the known occurrences of limestone of various grades in the Transvaal and portions of Bechuanaland and Zululand. The total production of lime for the year 1916 is given as 78,222 short tons, and the demand is likely to increase in the near future. In the district under review the most widespread calcareous rock is dolomite, which occurs in enormous quantities both in the crystalline rocks of earliest date and in the Potchefstroom System. Both of these types, however, contain too much magnesia for many purposes, so that the most valuable deposits from the economic point of view are the surface limestones so common in many parts of the Union.

The memoir also contains a special chapter by Dr. A. L. du Toit on the crystalline limestones or marbles of Port Shepstone and Hermansburg, Natal. Detailed mapping has shown that the marble of Port Shepstone is a bent and twisted mass, enveloped and penetrated by sheets of igneous material; the limestone must have a thickness of several thousand feet, and the metamorphism produced in it is of extraordinary theoretical interest. A detailed description is promised in a future publication.

R. H. R.

XI.—Structural and Glacial Features of the Hurunui Valley. By R. Speight, M.Sc., F.G.S. Trans. New Zealand Institute, vol. l, pp. 93–105, 1917.

THE chief interest of this valley is that it is an excellent example of a process of river development which is described by the author, following Dr. Cotton, as "ante-consequent". The geological history of the district is as follows: On an incompletely levelled surface of greywacke a series of Tertiary beds consisting of limestones, marls, greensands, and conglomerates was laid down, the uppermost of these being of Pliocene age. As these beds rose from the sea a system of consequent drainage was established on the surface of the land with sub-parallel streams running eastwards. When these rivers had established their courses folding and faulting took place along lines inclined at about 45° to the course of the streams. These movements produced a number of parallel intermontane basins filled with Tertiary rocks and separated by ridges of greywacke, and along these basins most of the tributaries flow to the main stream. These movements were of quite recent date and must have been very slow, since though in the upper parts of its course the direction of the stream is somewhat affected by them, in its lower reaches the river was able to preserve the direction of its channel and cuts straight through the greywacke ridges separating the basins along what must have been its original line. In this respect the Hurunui River is exceptional among the rivers of this region, since the courses of similar streams to the north have been much disturbed by these movements.

In the succeeding Pleistocene glaciation the ice probably did not penetrate to the lower portions of the valley, but the upper parts were filled with glaciers and show evidence of strong ice action. On the northern branch of the river, the ice, after arriving at the head of a large lake called Lake Sumner, split into several distributaries which passed over cols between the hills standing inside a right angle formed by a bend in the course of the river. These cols have consequently been lowered, partly by the cutting back of the corries at the heads of the valleys running down from them and partly by the ice streams flowing over them from above. Lower down at the end of the eastern limb of the right angle these distributaries united with the main glacier and were also joined by that from the south branch of the river.

W. H. W.

XII.—The Geology of Banks Peninsula. By R. Speight, M.Sc., F.G.S. Trans. New Zealand Institute, vol. xlix, pp. 365–92, with 3 plates and 4 figures, 1916.

BANKS Peninsula, which is situated nearly in the middle of the east coast of the South Island of New Zealand, is a mass of volcanic rocks about 25 miles long by 18 wide, projecting almost at right angles from the coast. The surface is very hilly and rises to a height of between 2,700 and 3,000 feet in several peaks. It is bounded on the north, east, and south-east by the sea, on the west

by low-lying marshy plains, and on the south-west by a large shallow lake, Lake Ellesmere, which is separated from the sea by a long narrow shingle spit. The volcanic rocks were to a great extent poured out from two vents which are now represented by the two large calderas of Lyttelton Harbour in the western and Akaroa Harbour in the eastern portion of the peninsula. These calderas have been converted into fjord-like inlets by erosion, and open on to the north-west and south-east coasts respectively. Part of the drainage of the region flows into the harbours, but most of it is roughly radial, and the consequent streams flowing outwards from the lips of the calderas enter the sea in a series of openings of the ria type which indicate recent submergence.

The geological foundations of the peninsula are a series of slates and greywackes which probably belong to the Trias–Jura Maitai system. On these rest the volcanics, which belong to four distinct periods of activity. The rocks belonging to the first phase are rhyolitic, and rest on the upturned edges of the older rocks; they are nearly all lavas, with only one irregularly distributed fragmentary deposit at the base. The vent was situated near Lyttelton, and, by analogy with similar rocks elsewhere, the eruptions probably took place in Cretaceous times. The second phase was marked by the building up of the two great volcanoes whose sites are occupied by the calderas of Lyttelton and Akaroa Harbours. Both these mountains were made up of basaltic material and were composite cones of alternating lavas and fragmental deposits; they were both probably at least 10,000 feet in height. The lavas vary from fine-grained basalts to rocks largely made up of felspar phenocrysts. This volcanic phase was followed by a dyke phase. These dykes are mostly trachyte, but some are andesite and basalt; they have a roughly radial arrangement which allows the position of the vents to be determined with tolerable certainty. The strike is not, however, constantly radial, and mutual intersections of the dykes are numerous. In the Akaroa area there is a large mass of coarse-grained hornblende syenite; this may be associated with the dykes, but it is cut by some of them and is probably part of the original land mass.

Before the next volcanic phase the calderas had attained a form not far removed from that which they have at present; during this phase basaltic lavas were poured out from a vent in the neighbourhood of Mt. Herbert, about half-way between Lyttelton and Akaroa, the date of the eruptions being probably Pliocene.

The last volcanic phase was that which produced the basaltic flows and ashes of Quail Island in Lyttelton Harbour. The island is in the middle of the caldera and probably marks a final outburst of this vent.

Some time after this last event the land was depressed to an extent of at least 700 feet, as may be shown by the occurrence of peat beds at this depth in boreholes in the plains to the west, and this movement has only lately given place to one of slight emergence.

The author holds that the calderas are chiefly the product of subaerial erosion, partly river and partly wave action. There must

have been an explosion to produce a hole of sufficient size for the rivers to work in, as the original crater would never have been large enough; but no great part of the excavation can have been done in this way, since, though the calderas were formed before the outpouring of the lavas of the third volcanic phase, there is no fragmental deposit at their base, such as must have been produced by so great an explosion. The forms of the inner slopes are also more in accordance with the theory of river erosion. After the initial explosions, then, the cone was breached, either by a lava-flow or by the cutting back of a stream, and finally carved out to its present shape by subaerial agencies.

XIII.—The Adirondack Intrusives.

The Problem of the Anorthosites. By N. L. Bowen. Journal of Geology, vol. xxv, pp. 209–43, 1917.

Structure of the Anorthosite Body in the Adirondacks. By H. P. Cushing. Ibid., pp. 501–9.

Adirondack Intrusives. By N. L. Bowen. Ibid., pp. 509–12.

Adirondack Intrusives. By H. P. Cushing. Ibid., pp. 512–14.

IN the first paper Dr. Bowen discusses the origin of anorthosites in general, with special reference to those of the Adirondacks and of Morin, Canada. His general conclusion is that anorthosites are produced by the straining off of femic constituents by gravity from a gabbroid magma; at a later stage of the cooling the crystals of more basic plagioclase sink in their turn, forming the anorthosite mass, while the acid residue forms a syenite. The Adirondack complex is thus interpreted as a sheet-like mass with syenite above and anorthosite below.

In the second paper Professor Cushing expresses his general agreement with Dr. Bowen's views as to the origin of the anorthosites, but dissents from his interpretation of the field relations; he concludes that the syenite does not form an overlying sheet, but is mainly intrusive into the anorthosite, and the border of gabbro is to be regarded as a chilled margin. The two remaining papers continue the discussion of the points raised in the previous ones.

R. H. R.

REPORTS AND PROCEEDINGS.

I.—Edinburgh Geological Society.

March 20.—Dr. M'Lintock, Vice-President, in the Chair. (Issued October 11, 1918.)

1. "Limits of the Valley Glaciation in the Basin of the Dee." By Dr. Bremner.

In late Glacial times an ice-stream descended the upper Dee valley and, reinforced by affluents from Glenmuick and Glengairn, formed a great valley glacier that extended to a point fully a mile east of Dinnet railway station. The limits of its extension have

been determined by mapping the lateral and terminal moraines, marginal channels, and overwash deposits.

That the period of the valley glaciers formed a distinct phase in the history of the Ice Age is suggested by the occurrence between Cambus o' May and Dinnet of two boulder-clays: in two sections one can be seen superposed upon the other. The upper, the moraine profonde of the valley glacier, differs in composition and resistance to denudation from the lower, the product of the ice-sheet.

The whole or a great part of Glentanner, also, seems to have been occupied by a valley glacier.

2. "Occurrences of Old Red Sandstone in and near Aberdeen." By Dr. Bremner.

Old Red Sandstone is known to occur at seven different places over a considerable area within the city boundaries. In a bore at Sandilands Chemical Works the rock was encountered about 96 feet below O.D., and at 625 feet below O.D. it had not been bottomed. A Lemon Street bore entered it at 60 to 65 feet below O.D. At Woolmanhill it was encountered at sea-level, and found to have a total thickness of 189 feet; the bore was carried down 9 feet into the underlying metamorphic rock.

A small outcrop occurs in the banks of the Millden Burn, 6 miles north of Aberdeen.

All the rock proved is of Middle Old Red type.

3. "Notes on the Lochend Sill." By Robert Allan, B.Sc.

Some particular features in the petrology of the Essexite intrusion, previously described in the G.S. Memoir on the Rocks of the Neighbourhood of Edinburgh, were pointed out and illustrated by means of lantern views. The great variation which occurs throughout the sill, the characteristic feature of which is the presence of a soda-rich felspar, was also indicated. Particular slides were shown in which the relationship between the ilmenite, biotite, and chlorite present in the rock was brought out. Both at Hawkhill and Lochend portions of the intrusion have a spotted appearance, and these spots in many instances were found to consist mainly of analcite, and seemed to be of the nature of ocelli, or local segregations of the residual magma late in crystallizing out.

II.—Liverpool Geological Society.

October 8, 1918.—J. C. M. Given, M.D., M.R.C.P., F.G.S., President, in the Chair.

At the annual meeting of this Society, which now enters upon its sixtieth session, the President read an address upon "The Geological Position of Primates", in which he gave an account of recent research and discoveries bearing upon the origin and antiquity of man. The writings of Rutot and others on the so-called "Eoliths", which they claim to be of human manufacture, would take back man's origin to at least Miocene times, and had led to wild speculations on the subject, so that it seemed profitable to consider the question, not from the standpoint of the earliest appearance of man,

but of his predecessors in mammalian evolution, for if man belongs, as he certainly does, to the highest order of the mammalia, namely, the Primates, it must be a waste of time to try to prove him to be earlier than these his manifest ancestors. The classification of the mammalia was first reviewed, and the modern distribution of the higher mammals over the face of the earth examined, as a preliminary to describing their fossil ancestors and geological relations. A description followed of the zoogeographical areas of the earth's surface, and their characteristic faunas, and it was made clear that the Primates first appeared as very primitive lemurs in the Upper Eocene, as in the Wasatch formation of Wyoming, U.S.A., and in Europe in the Phosphorites of the Paris Basin, as also in Switzerland, and in Hampshire in this country, but that not until the Oligocene of the Egyptian Fayoum is reached are any traces of the real ape tribe to be found. In the Miocene they can be discerned a little more plainly, but only in the Pliocene do the larger man-like apes first manifest themselves. Therefore, in spite of the "Eoliths", it would seem, *a priori*, to be very unlikely that *Homo sapiens*, or his immediate lineal ancestors in the Anthropoidea, will be found earlier than this.

OBITUARY.

LIEUT. GRAHAM JOHNS,
Scots Guards.

Lieut. Graham Johns, Scots Guards, son of Mr. and Mrs. Cosmo Johns, of Sheffield, was killed in action on September 27. He matriculated at Caius College, Cambridge, but did not go into residence. He was severely wounded at Ypres, July, 1917, and returned to the Front in March this year.

THE RIGHT REV. BISHOP JOHN MITCHINSON,
D.C.L., D.D., F.G.S.

Born September 23, 1833. Died September 25, 1918.

We regret to record the death of Bishop Mitchinson, Master of Pembroke College, Oxford, who was a lifelong student of geology and a devoted friend of geologists. From 1859 until 1873 he was Head Master of the King's School, Canterbury; from 1873 until 1881 he was Bishop of Barbados; from 1881 until 1899 he held the benefice of Sibstone, Leicestershire, and acted as deputy in much episcopal work; and in 1899 he was elected Master of Pembroke. While in Barbados he spent part of his leisure in making a collection of fossils, which he gave to the British Museum in 1892. While at home he made numerous excursions in search of fossils, and eventually brought together a good representative series, which he carefully studied and arranged in cabinets. After reserving for Oxford a few specimens, among which was the type of *Olenus Mitchinsoni* from the Shineton Shales, described by Dr. H. H. Thomas